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ABSTRACT

An introductory chapter, "Contemporary Issues in Gifted Education" by Julia Dreyden and Shelagh Gallagher, summarizes National Science Foundation policy concerning development of new science and mathematics curricula and the work of the Talent Identification Program. Major conference papers and responses are then presented: "Developing Academic Talent: A Problem of Vertical Integration" (Alvin Trivelpiece); "Student Panel Discussion" (Zerrick Bynum et al.); "The Cognitive Roots of Scientific and Mathematical Ability" (David Perkins and Rebecca Simmons); "The Importance of Developing Leadership Potential of Youth with Talent in Mathematics and Science" (Kenneth Clark); "Purchase and Possession: A National Database for the Scientifically, Mathematically and Technologically Talented" (Robert Sawyer); "The Federal Republic of Germany's Response to the Need for Talent in Mathematics" (Ernst Blanke); "Current Federal Education Policy Regarding the Academically Talented in Mathematics, Science and Technology" (Krista Stewart); "Creating Scholar/Practitioner Networks for the Most Capable Youth in Mathematics, Science and Technology" (Don Phillips); "Brilliant Women for Science, Mathematics and Engineering: Getting More than We Deserve?" (Shirley Malcolm); "Better Measures: Developing More Minority Mathematicians and Scientists" (Judith Griffin); "Motivating the Most Capable Youths in Mathematics and Science" (Kevin Bartkovich); and "The Development of Educational Support Systems for the Academically Talented: The Talent Search Approach" (William Durden). (JDD)

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A CONFERENCE ON ACADEMIC TALENT

DEVELOPING TALENT IN MATHEMATICS, SCIENCE AND TECHNOLOGY

DUKE UNIVERSITY TALENT IDENTIFICATION PROGRAM
NATIONAL SCIENCE FOUNDATION

MARCH 28, 29 AND 30, 1988
DURHAM, NORTH CAROLINA

EC 220285

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THE PROCEEDINGS OF THE TALENT IDENTIFICATION PROGRAM/ NATIONAL SCIENCE FOUNDATION CONFERENCE ON ACADEMIC TALENT

March 28, 29 and 30, 1988
Durham, North Carolina

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CHAPTER I

INTRODUCTION

CONTEMPORARY ISSUES IN GIFTED EDUCATION

The Talent Identification Program/National Science Foundation (TIP/NSF) Conference on Academic Talent was a national, by-invitation-only, conference on issues associated with the research and successful delivery of educational services to academically talented students. Attendance at the conference was by invitation only and included those whose expertise would contribute to the conference goal of developing a research agenda for increasing the participation of academically gifted youth in the study of mathematics, science and engineering. Participants included speakers, who made formal presentations; discussants, who responded to the presentations with prepared remarks; and others whose professional responsibilities linked them to the conference goal of gifted youth undertaking study in mathematics, science and technology. A list of conference participants and their institutional affiliations reflects the range of educational and scientific institutions which were represented at the conference. Speakers and discussants were selected not only for their professional expertise, but also to represent the perspectives of four groups specifically defined by NSF: underrepresented minorities; practicing scientists; women; and teachers. The TIP/NSF Conference took place on March 28, 29 and 30, 1988, at the Sheraton University Center, Durham, NC.

The thematic content of the proceedings reflects the interest and concerns of the TIP executive staff as they discussed and developed, over the course of nearly two years, the proposal to the NSF. These discussions focused on issues of giftedness, recognizing that questions of program evaluation were linked in interesting and significant ways to those of identification, and that these were related to issues of national educational policy. Theoretical questions of the antecedents of talent and their relationship to identification procedures, programs, and policy formulation also arose as the purposes and anticipated outcomes of the conference began to be articulated.

This volume presents the proceedings of the conference--the keynote address, the student panel discussion, the invited dinner speech, and the nine major presentations and responses. The introductory chapter presents summaries of current NSF policy in regard to the development of new science and mathematics curricula and of the work of TIP in its efforts to reach and foster the talent of gifted youth. Also included in the introduction is an overview of the conference presentations, highlighting the salient points of each. We believe these proceedings represent some of the most well-informed, experienced and earnest thinking, to date, in the subjects of research, science and mathematics education, and the gifted child.

BACKGROUND TO THE CONFERENCE

NSF Policy: An Overview[1]

Since the early 1980's, the federal government has been taking an increased interest in secondary education policy. Various federal agencies, notably the National Science Foundation and the U.S. Department of Education, are working to reform education in mathematics and science, particularly at the K-12 level. In an attempt to create a greater number of science learners, the NSF has focused on the revitalization of a K-12 science and mathematics curricula, the science education of teaching professionals, and institutional infrastructure of K-12 science education.

In the opinion of the NSF officials, the current science curriculum of public schools emphasizes textbook knowledge over the development of intellectual skills. The elementary mathematics programs consist almost entirely of rote computation, whereas the advanced courses are assigned arbitrarily to certain grade levels and both mathematics and science courses are deficient in incorporating technology such as computers, or even calculators. The NSF's conception of the new science and mathematics education includes an interdisciplinary approach to the sciences, the integration of technology into the curricula, the investigation of the social and economic impacts of science and technology, encouraging in-depth and experiential learning, and a heterogenous instructional repertoire appropriate to a student population heterogenous on the basis of age and background.

The success of the restructuring of the curricula will be directly dependent upon the capability of the teachers. Currently, the majority of teachers are underqualified primarily because of the relatively low pay and the status of the teaching profession. By building a network of professionals, research scientists, engineers, and teachers, the community of practitioners concerned about science and mathematics education can be strengthened.

These two elements of instruction--quality of curricula and of teachers--are not the only influences on mathematics and science education. Within the organization of the local school system, policies, allocation of funds, teacher training programs, and administrative support which are inadequate or inappropriate also inhibit the ability of the NSF and wider professional circles to promote change. State level requirements on testing, graduation, and textbook use also limit the possibilities for changes in curricula. The responsibility of developing curricula should be removed from the control of publishers, media, scientific organizations, private consultants, test publishers, legislatures, and departments of education. The roles of these institutions should be redefined so that they work together to support different types of learning.

The NSF, working with other federal agencies, is in an excellent position to lead the reform of science education programs. It has a budget of $108 million for K-12 science education for fiscal 1988, and has gained a great deal of credibility through the many successful projects it has supported in the past. In the 1960's and early 1970's, the NSF developed curricula which are still in use today. Recently, it has trained "leadership teachers", professionals who, together with curriculum specialists and others, become a valuable resource and support network for other teachers. The NSF's access to both scientific and educational communities facilitates networking among scientific educators, scholars, and practitioners.

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[1] Sources for this section are Knapp, Stearns, St. John and Zucker (1988) and *Higher Education and National Affairs* (2/15/88).

The NSF is currently using two different, though not necessarily opposing, strategies:

1. To upgrade curricula through widespread, incremental, short-term investments.

2. To implement radical, long-term improvements by searching for the state of the art, and "breakthroughs" in instructional strategies.

Realistically, the outcome of the struggle for policy change is difficult to predict; it will be affected by several factors outside of the NSF's control, including federal policy and the societal reactions to attempted change. Congress may not maintain an interest in science education over several years; however, its work in this area in the 1960's and early 1970's demonstrates that maintaining this interest is possible. Right now, the preoccupation with maintaining economic competitiveness is likely to sustain the desire to improve mathematics and science education.

Erich Bloch, Director of the NSF, in a 1988 address to the American Physical Society and the American Association of Physics Teachers, pointed out that the decrease in the size of the college population of the United States, as well as the decrease in the rate of college students' choosing majors in the sciences and engineering, threatens the nation's technological preeminence. A possible remedy is for the federal government to allocate sufficient money for the improvement of science and technology programs. Bloch also stated that the NSF received a budget of $1.7 billion for the 1988 fiscal year--only a six percent increase over last year.

The societal factors at work are more difficult to identify than those due to federal policy. Certain educational strategies are so entrenched in American society that gaining support for dramatic change will be difficult. One encouraging note may be found in a recent survey of business, university, and state leaders, who identified research and education as the most important factors in the future of U.S. competitiveness. Education at the K-12 levels was cited as a particular concern.

The NSF has formulated policy to have a direct and enduring impact on the mathematics, science and technological curricula in the American public schools. Grant support from the NSF encompasses a range of activities implicated in the upgrading of curricula, including studies of cognition, especially as they result in improved classroom materials and better teacher preparation. The efforts of the Sputnik era, which resulted in quality science curricular units still in use today, serves as the model for current NSF policy.

The Talent Identification Program

One strategy in facilitating the educational development of academically talented adolescents is to involve them in existing regional talent searches. Currently, four searches, covering the 50 states, employ out-of-level measures of domain-specific achievement to evaluate the degree of students' academic giftedness, and subsequently, to direct extremely able students into programs appropriate to their level of ability.

The Duke University Talent Identification Program (TIP), the largest of the four regional talent searches, is a non-profit organization directed toward identifying academically able adolescents and assisting in their educational development (Sawyer, 1985a). The program also provides a range of student services, including counseling information, to assist students in better understanding their standardized test scores; a national guide to programs outside the home school which can provide challenging academic experiences; and assistance in the placement of these gifted young people in colleges and universities. The program also includes a Research Division, which conducts investigations to increase the understanding of intellectual giftedness, the familial and contextual factors coincident with academic talent, and the academic and psychosocial needs of gifted adolescents.

The TIP Talent Search covers sixteen states including Alabama, Arkansas, Florida, Georgia, Iowa, Kansas, Kentucky, Louisiana, Mississippi, Missouri, North Carolina, Nebraska, Oklahoma, South Carolina, Tennessee, and Texas. Approximately 14,200 public and private schools with seventh grades lie within TIP's catchment area. Through the dissemination of informational materials to administrators, guidance counselors, and teachers, students are informed of the Search procedures. A student must score at or above the 97th percentile on the mathematics or verbal reasoning component or composite score of an age/grade-normed achievement test, such as the Iowa Test of Basic Skills (ITBS) or the California Achievement Test (CAT), to be eligible for the Search. Students applying to the Talent Search are to take the ACT or the SAT examinations normally used to assess the entry qualifications of high school seniors. The practice of out-of-level testing (Sawyer, 1985a) allows discrimination of a range of abilities within a "homogeneously" able sample. SAT scores within this group have been shown to be reliable predictors of ability and achievement in mathematics (Stanley, 1977-78) and of achievement in academically rigorous, accelerated programs (Sawyer, 1985b).

The results of the 1988 Talent Search demonstrated that seventh graders can do extremely well on the ACT or SAT. Of the Search participants who took one of the standardized tests, about one in four scored at least as high as the average college-bound high school senior on either the mathematics, verbal, or language use component of the tests. The large majority of these students take the examinations without the benefit of the four years of preparatory work and formal educational experience obtained by the usual test takers--high school juniors and seniors.

In recognition of their outstanding accomplishment, the higher scoring students are invited to ceremonies in their states and are presented with Certificates of Distinction. The top-scoring students are invited to a Grand Ceremony at Duke University where they receive awards of gifts and scholarships.

TIP also offers enriched or accelerated learning programs designed to challenge students to their fullest potential. The centerpiece of the educational programs is the Summer Residential Program which includes two three-week semesters and is held on the Duke University campus. To qualify for the Summer Residential Program students must score at or above the seventy-third percentile of the college-bound high-school seniors in the mathematics or verbal component of either of the designated standardized tests. Other services provided by TIP include additional on-campus programs, such as the Precollege and Commuter Programs, and outreach to the participating schools, including the creation and distribution of manuals for Advanced Placement courses for many different subjects.

THE CONFERENCE: AN OVERVIEW OF MAJOR THEMES

The conference hosted two special presentations, the keynote address and a student panel discussion. The keynote addressed the problem of maintaining the vitality of the individual, in physical well-being and intellect, in the context of institutions which are oftentimes governed by policies unresponsive to individual needs. The student panel, consisting of four young people studying mathematics or science, critiqued the educational services available to them from the perspective of the academically gifted student.

The keynote and responses introduced themes which were echoed throughout the conference in various forms and from many different perspectives. In general, these recurring themes were:

1. Intellectual curiosity is an essential element of high quality scientific and mathematical thinking.
2. The inadequate condition of science and mathematics education in America is reminiscent of that of the "Sputnik era." This comparison illustrates that high quality education requires vigilance and that integrating federal and local efforts can have a measurable impact on improving the quality of education.
3. Efforts to upgrade education for both talented and competent students are warranted, given the inadequate science and mathematics education currently offered in the representative American school.
4. Resistance to intervention in local education, while protecting the diversity of the system, frequently inhibits efforts to improve education.

Other speakers introduced major themes which, together with the keynote concerns, formed the core of issues upon which the conference focused. These latter are:

5. The decreasing size of the 18-21 year-old cohort aggravates the need for increased numbers of graduates in the fields of science, mathematics, and technology to meet the need of the nation anticipated by the twenty-first century.

6. The cultivation of the talents of underrepresented groups, i.e., minorities and females, is a promising strategy for meeting the nation's technological needs.

7. Restricting the study of predictors of achievement solely to psychometric measures leads to too-narrow a picture of talent. Use of these measures of ability should be tempered with the cautions that:

    a. In general, psychometric measure underpredict achievement for females and minorities.

    b. Research in the noncognitive factors rooted both in the personality and the environment will broaden our understanding of the underpinnings of career and life achievement.

Keynote: Scientific Curiosity and the Integration of Systems

Dr. Alvin Trivelpiece, the keynote speaker, is the Executive Officer of the American Association for the Advancement of Science (AAAS). In his address, he emphasized the need to protect and nurture curiosity as the quality most crucial to the flourishing of scientific talent, and the problem of integrating education from preschool to college. Subsequent educational efforts must build on those preceding, and the course of an individual's education should be informed by the need to foster and protect the student's intellectual growth.

Keeping curiosity alive is central to developing the habits of inquiry which underpin scientific interest and ability. The mastery of the theoretical principles of a discipline should not supplant the development of natural curiosity. The importance of curiosity compared to mastery of theory should caution educators to pay particular attention to the danger of diminishing children's interest and enthusiasm for learning.

Programs must become the arena where theoretical underpinnings and policy provisions come together. Programs are not simply the structured environment of a single classroom, Trivelpiece observed, but a sequence of educational supports which are vertically integrated, that build on the productive outcomes of the preceding step, and move toward meeting the academic requirements of higher education and the manpower requirements of the national workforce.

The responses to the keynote speech focused on similar themes: nurturance of talent and the integration of social policies that provide adequate support and protection for the development of the child. The questions of why programs from the "Sputnik era" did not survive, and why mathematics and science education are again neglected, are matters needing national attention. The source of these problems is rooted in society's conflicting values, particularly with regard to the intrusion of government into the family. These conflicting values are also partly responsible for the lack of vertical integration of educational policy in the United States.

An indication of the obvious need to attend to specific problems in the educational system can be found in the similarities of the presentations by the keynote speaker and the four students participating in the panel discussion. Trivelpiece presented the broad statement of the problems; the students provided specific examples to justify his case.

Trivelpiece spoke of the importance of maintaining curiosity in order to stimulate students' continued interest in mathematics and science careers. The students, in their criticisms of the bland academic diet they received in the regular classroom, reinforced this claim insisting that the environment of the regular classroom often deterred rather than facilitated learning in their areas of interests. The students suggested that the presence of special programs which allowed them to learn at an appropriate pace was not only a relief, but a necessary component in their progress toward careers in mathematics, science, or engineering.

Creating a unified effort among the various levels of education was a major point in the keynote address. The student panel supported this concept by noting how disjointed their own education had been, being provided with appropriate programming only at special moments in the course of their education, and at other times being left to fend for themselves in the regular classroom atmosphere. One of the students mentioned that as a result of changing criteria for identification from grade to grade the very presence of talent could be made to seem like a transient component of her personality.

Finally, the students' presentation underscored the concern for broadening the scope of gifted education to include more members of underpresented groups. In fact, the very composition of the panel served as a reminder of the diverse nature of the population of gifted students. Two white females, a white male and a black male were members of the panel. Each person represented a unique set of needs and a different approach to programming. The diverse nature of the group was also made clear in the presentations when a female student brought forth evidence of gender discrimination, and when the black male spoke of his special motivation to achieve in order to be a role model to other students.

Theory and Research in Academic Talent

The theory of intelligence and its academic, psychological, and social correlates has a special bearing on the study of high cognitive ability. Talent is a valuable human resource which potentially yields very high return rates on an investment. A large proportion of individuals who enter the disciplines targeted for critical shortfalls by the year 2000 will come from the cohorts of talented students identified by TIP and similar programs for talented students.

One question dominated the discussion of theory: What are the special characteristics of the child, either cognitive or affective, which cause or enable him or her to learn at an accelerated pace? The theory that is developed in response to these questions, in turn, bears on the delivery of services and what educational and social supports respond best to the child's needs. A second question arising in the discussion of theory reiterated a recurring theme: How do the results of research on the gifted generalize to the population of competent learners? The discussion focusing on the theoretical aspects of academic giftedness addressed three aspects of cognitive theory:

1. Models that account for achieved and precursor abilities and how these are measured or predicted.
2. Models that account for changes in the measure of cognitive ability, including methods of alternative representations.
3. Models that include noncognitive factors in accounting for cognitive development.

The second presentation on this topic focused on leadership theory and the need for the academically talented to participate in leadership. The third presentation discussed the needs and means for developing a national database to study scientific, mathematical and technological talent.

Cognitive Theory and Scientific Talent. The first presentation, by Perkins and Simmons, explored the underpinnings of contemporary theories of cognition in an attempt to account for and predict scientific and mathematical ability. Achieved ability, according to these authors, is the combination of structures and processes that comprise the individual's comprehension and problem solving capacity in a discipline. Precursor abilities must be at some "remove" from the domain ability being tested, otherwise the distinction between achieved and precursor abilities is collapsed.

The discussion of the cognitive roots of abilities was advanced with a dialectical model, contrasting what is with what lies beyond cognitive attributes. Expert behavior, an essential component of achieved ability, is characterized by three attributes:

1. A "quick, recognition-like orientation to the 'deep structure' of problems".
2. A superior ability to remember typical but not atypical situations.
3. The ability to reason forward, using context-specific models that permit access to relevant domain-specific principles.

The limits of expertise are discovered when an atypical situation calls for innovative use of a discipline's principles. Beyond expertise, thinking that can broach atypical situations must use general and specific knowledge flexibly to solve a problem. Flexible thinking, then, exhibits the quality of understanding that moves beyond simple expertise.

Problem solving, emphasized in mathematics and science, is an attribute of achieved ability distinct from expert behavior and understanding. Polya (1957) encouraged the development of a heuristic of problem solving. This technique is limited, however, by students failing to apply the heuristic while attempting to solve the problem. The notion of problem management, in which students gain a self-conscious, "executive" control (Schoenfeld, 1985) of problem solving skills, was introduced as a means of enhancing problem solving behavior. Beyond problem management is problem finding, perhaps the most creative arena of performance for expert mathematicians and scientists.

The verification of achieved abilities is a relatively reliable phenomenon given the clearly operationalized definitions that exist for expert behaviors in various disciplines. But the question remains as to what kinds of abilities, if any, predict or explain subsequent outstanding achievement.

An alternative model to intelligence theories is the developmental model, the most famous being that of Piaget, who posited a four-stage theory. Upon reviewing the predictive power of precursor versus achieved abilities theories, however, we find that achieved abilities and even personality factors are much better predictors. Theories of precursor abilities are important because they force the researcher to look with a broader perspective at the individual and environmental traits which occur with giftedness.

Perhaps the most important feature about the existing theoretical structures is that they help to identify what questions would be most useful to ask about how cognitive development occurs among the academically talented. The Perkins and Simmons paper provided a useful overview of this problem for the domains of science and mathematics. It acknowledged that general problem solving may be at the heart of good performance and suggested that the ability to find and formulate problems is important, as well. The first response to this presentation introduced an additional concept, "alternative representations," which helped to expand the framework for studying academic talent and described a new way to study problem finding in that context.

The Alternative Representations Approach. Two simple notions introduce the alternative representations approach. First, all ideas can be represented in many different ways--such as sentences, lists, outlines, tree diagrams, matrices, graphs, and pictures. This is true no matter whether the content involves academic or everyday information, is simple or complex, brief or extensive in length. Second, the way a given idea is presented has clear cognitive consequences. That is, representations affect cognitive processes such as perception, memory, concept information, comprehension, and problem solving. To illustrate these notions, examples from specific science domains (e.g., chemistry) as well as some which cut across domains (e.g., data analysis) were used. The discussion of chemistry molecules illustrates the concept and some of the implications of alternative representations.

Students have difficulty learning organic chemistry for a variety of reasons, including the sheer amount and complexity of the information involved. However, the notation systems chemists use to represent three-dimensional molecules in two-dimensional form (in textbooks, on blackboards) may be part of the problem (Day, 1984).

Students who participated in experiments in alternative representations were given a notational form and asked to determine whether they showed the same or different molecules, independent of notational variations. Their performance depended on what notational system was used; one system was easy to use and led to superior performance, while another was difficult and led to inferior performance.

Other experiments in data analysis investigated how well students can think scientifically. To study this question, students were given a small set of data from a simple experiment and asked to extract some basic results. Providing the same data in alternative representations affects their ability to solve simple problems accurately. More interestingly, though, such representations also affect their ability to find and solve more subtle problems embedded in the data. Subjects in the favorable representation groups, then, look as if they possess greater "scientific talent."

The alternative representations approach holds some interesting implications for understanding "talent" and for considering educational practice for both talented and competent students. The experiments by Day and others show that good students can be made to *look* more or less talented in a given domain simply by giving them specific representations of key information. Perhaps what sets talented students apart from the rest is that they already know how to represent concepts in many ways and to select representations that work well for various tasks. Perhaps the ability to use alternative representations unlocks "talent;" if so, then instruction might well include explicit alternative representations of important concepts.

Contemporary Cognitive Theory. Dr. Edward Zigler's discussion of theory shifted the perpective on theory from close scrutiny of models of cognition to a broad-scoped discussion of cognitive theory in the societal context. The discussion opened with the observation that contemporary cognitive theory has three paradigms to work with:

1. Psychometric
2. Cognitive/developmental
3. Information processing

Although each of these models contributes to our understanding of intelligence, the psychometric model has not been bettered for its predictive power. Over the next 30 years, however, it may be possible to overcome inherent bias in testing simply by tapping an individual's physiology. This path of theoretical development seems more likely to be productive than that of, for example, whether *g* or *s* is right, as any complete model will have to incorporate both concepts. The limitations of both is that they are tied to the psychometric paradigm, which unfortunately, is thought of as distinct from the cognitive/developmental approach.

In regard to information processing, it seems too early to determine whether the triarchic theory of intelligence will add to predictive ability of theory. Among the three models, the psychometric, cognitive/developmental and information processing, the model preferred for its contribution to understanding intelligence is the cognitive/developmental model. Developmental models help illuminate our understanding of giftedness by putting intelligence in the context of *rate* of development. The speed at which an individual acquires knowledge and understanding is a critical element in any theory attempting to identify precursor abilities. A second important element has to do with individual differences, that is, the final stage at which a person's cognitive development stops.

Another issue in development is that of creativity versus intelligence. Most theorists agree that intelligence is a necessary but not sufficient component of creativity. These models bring attention to a persistent dilemma in the discussion of intelligence, and in particular in measuring intelligence with intelligence quotients. Attempts to define creativity always sound like the best way to define intelligence, suggesting that measures of creativity ought to be included in intelligence tests.

When undertaking the explanation of this phenomenon, the issue of motivation must not be neglected. Although much has been said about environment and the influence of parents in producing genius, these factors are not generally those that produce most geniuses and creative people. The extrinsic motivation provided by the environment is markedly different from intrinsic or affectance motivation. The latter, working for the sheer joy of using the intellect, is much more likely to characterize people of extraordinary ability and achievement.

Zigler's final point addressed the question of what happens to the curiosity and natural inquisitiveness that is characteristic of the young child. Recognizing that play is essential to preserving and developing curiosity and self-discovery is the first step. Effective school leadership using the resources, from the federal government to local school systems, could also improve education.

Theory of Leadership and the Gifted

While the discussion of cognitive theory explored on an individual scale the environmental and cognitive events associated with the occurrence of a high level of mental ability, the discussion of leadership theory explored the implications of talent, its responsibilities and the societal vehicles which facilitate its expression. The gifted play an important role in improving the quality of society; nurturing talent is important to ensure that society's human resource needs are met. Conversely, individuals with scientific ability must be prepared to assume roles of leadership to improve the quality of the society.

In regard to developing talent in science, technology and mathematics, a liberal education that imbues knowledge of and loyalty to societal structures and institutions is essential. Educational programs dedicated to these goals must develop in their participants skills of rigorous, analytical thinking. The cultivation of these qualities in talented individuals will result, ultimately, in good governance and human relations.

The respondents to the initial presentation concurred with the central thesis that those educated in scientific and technological careers are needed in the broader leadership roles of the society. This argument finds strong support among contemporary students of the problem of developing sufficient scientific talent for the future. It is important to note that scientists and engineers educated in America receive broader and better balanced educations than students of history or philosophy. The latter tend to be oblivious to the importance of scientific knowledge and to the excitement of current scientific developments and their potential to change our lives. Scientists, on the other hand, are more aware of the substance of the change that is occurring in our society.

Other important points made by the participants in this session were:

1. Scientists and engineers appear to be filling a disproportionately large share of leadership roles;
2. The size of the scientific/technological talent pool is dwindling and may not be sufficient to meet the nation's human resource requirements;
3. One means of solving this problem is to begin cultivating the scientific talent among females and minorities;
4. The criteria currently used to identify future professionals, i.e., largely standardized test scores, are too circumscribed.

The problem of finding enough scientific talent is compounded by the fact that scientific and engineering majors are recruited from among all high academic achievers; thus, the competition with other specializations intensifies. Adding leadership responsibilities to the possible life work of high academic achievers further increases the competition for available talent. One important approach to solving this problem is to begin cultivating the scientific talent among females and minorities. Another important strategy is to rethink the criteria that are used to identify future professionals.

Theoretical Basis of a National Database

Sawyer, in the proposal to establish a national database, spoke from the perspective of having data and needing appropriately powerful theory to interpret and make use of them. Consequently, this presentation identified many practical benefits of having a coherent theoretical basis for research.

The establishment of a national database would enhance the development of methodical and self-conscious research, helping to minimize redundancy, conserving scarce resources, and facilitating individual research undertakings. At the same time, theoretical issues identified as essential to effective utilization of a national database were strikingly similar to Zigler's discussion of cognitive theory. Specific topics which would promote a clearer understanding of mathematical and scientific talent within a development context include:

1. Investigation of developmental pace or rate.
2. The relationship among intellect, personality and socialization.
3. Factors bearing on educational and vocational choice and success.

4. Stress, resilience and coping behaviors.

5. The effects of educational interventions.

The discussion of the national database focused on the study of talent, how its manifestations change over the lifespan, and how the biological and psychosocial processes are associated with stability. Insight into these initial problems may help to answer questions of whether early identification is warranted, not only for the benefit of the society, but for the well-being of the child. In evaluating the use of interventions, questions of when and how to intervene must be finely-grained enough to look at whether there are relative effects on the component parts of talent, and with an eye to identifying possible risks. The considerable research on the correlates of resilience and stress, signaling the importance of self-efficacy and family functioning, must be extended to include gifted individuals.

In the subsequent discussion, it was observed that the concept of a national database would enable researchers to examine the nature of talent and the ways in which talent may be encouraged and developed in ways that would obviate the reactive posture of the educational community. The development of such a database, however, presents serious logistical difficulties, but there are a number of suggestions as to how data collection in support of a national database could be developed. It would be possible, for example, for local schools, using a prescribed format, to submit data to a national information center on a floppy disc. These data could be used to help colleges, industry, and private research foundations to identify pupils who could benefit from specific educational and work and research activities prior to finishing high school.

This discussion emphasized one of the themes voiced repeatedly by participants that all talents are valuable, and that all people, in one way or another, are talented. Our society has the resources to provide for the special needs of one group, while also providing opportunities for the larger group to develop their own skills to the fullest extent.

Summary

Discussion of theory ranged from consideration of practical problems to theoretical models for understanding and resolving these problems. A major concern was the increasing scarcity of talent not only for scientific and technological endeavors but also for societal leadership. The development of a cognitive model that would accurately predict success in these capacities would aid in the identification and developmental of talent. Unfortunately, the most clearly formulated theories tend to isolate cognitive from noncognitive factors relevant to life achievement. The limitations of psychometric testing to predict career success were noted, pointing to the need for a broader perspective that includes factors of motivation, environmental context, developmental events, and rate of change. Educators and legislators must be aware that, while test scores can be a convenient and valuable source of information, they are not the only source of information.

Educational and Legislative Policy in Support of Education for the Gifted

Considerations of policy focused primarily on the ways in which federal and state agencies may intervene in educational practice to meet societal needs for increased levels of expertise. Interventions were most often conceived in the form of financial support, with policy establishing parameters for the use of allocated funds. Generally, policy was defined at the national level as the legislative constraints placed on the disposition of funds and, additionally, at the state and local levels, as the criteria which circumscribe programs or agencies in order to implement certain priorities. Participants in this session tended to support policy that generated and funded a variety of programs. The degree to which monies are allocated for well-defined, coherent policies formed a strong thread of argument throughout the conference, with opinion favoring stronger, clearer policies in support of gifted and talented education. Policy priorities identified as means to satisfy scientific and technological human resource needs were:

1. Improved science and mathematics training and better remuneration for teachers;
2. Upgraded science and mathematics curricula, including instructional use of computers and telecommunications equipment;
3. A shift in recruitment strategies to emphasize minorities and females.
4. Better use of research and of scholar/practitioner networks in generating and disseminating research findings.

A major policy presentation was made by Ernst Blanke, Deputy Minister of Education the Federal Republic of Germany. Perhaps the most interesting aspect of Blanke's speech was the simlarity of educational concerns between the United States and Germany and, in particular, in the increasing needs for technological expertise and the strategies used to identify talent and foster its development.

Policy of the Federal Republic of Germany

Blanke spoke about the present needs of the Federal Republic of Germany for technological expertise and the strategies to nurture the development of academic talent in mathematics, science and technology. Although the labor market for mathematicians, scientists and engineers in the nation is relatively stable, major changes are expected that will require increased levels of technical knowledge. The Federal Republic of Germany enjoys a very high standard of living. To maintain this quality of life, "a constant stream of quality products, production techniques and services must be offered". Thus, development of academic talent, particularly in the fields of mathematics, science and technology, has been recognized since the early eighties as "a major task for education." Some of the means of promoting awareness of the need for expertise in certain fields are federal competitions, working groups at the school level, focusing on special subject areas, summer courses patterned on the accelerative models used in the United States, and in-service training for teachers. In the higher education sector, structures are emphasized which promote the admission of highly talented students to special study programs and their direct involvement in research activities.

Increased effort research in the Federal Republic of Germany is needed in three areas:

1. Finding a means of identifying talent and promoting its development through the training of third party providers.
2. Identifying the causes of the low participation of women in mathematics, science and engineering.
3. Exploring the use of leisure time to provide opportunities for the development of talent.

Policy at the National and Local Levels

The report on the current status of legislation relevant to the education of the gifted and talented observed that, in regard to federal policy on scientific and technological education of the academically talented, two points should be kept in mind:

1. Although much attention is given to both education of academically gifted and talented and in mathematics, science and technology, these topics are rarely addressed in the same breath.
2. Only about 8.7 percent of the total expenditures for elementary, secondary, and postsecondary education is contributed by the federal government. The total federal expenditure for elementary and secondary education is only 6.1 percent. Despite these relatively limited expenditures, federal legislation does have a significant impact on education at the local level.

Currently federal educational legislation has two major themes, equity and access, with emphasis being given to the role of education in maintaining economic competitiveness and national security.

Gifted and Talented. In legislation for the gifted and talented, the consistent theme is one of the need educate the best students to maintain the nation's competitive position as a world leader.

The Jacob K. Javits Gifted and Talented Children and Youth Education Act is the primary piece of legislation for the gifted to be introduced in the 100th Congress. The legislation provides, among other things, for the authorization of $25 million for fiscal 1988, for grants or contracts to State and local educational agencies, institutions of higher education; for establishing a National Center for Research and Development in the Education of Gifted and Talented Children and Youth; for at least half of the grants to be awarded to projects that service the economically disadvantaged.

Other legislation which would support the education of gifted children are the Chapter 2 Block Grants and several of legislation for special groups.

Mathematics, Science and Technology Education. Funding for improvement in mathematics and science in the omnibus education bill would be based on modification of the current EESA Title II.

A representative from the NSF expanded on discussion of policy embodied in legislation with a description of that agency's grant-making policy. The work of the NSF is directed toward upgrading the American educational system in stable and enduring ways. The issues of research and knowledge may not be treated as objectively as is necessary to clarify whether more knowledge is needed to achieve this goal of cultivating scientific talent. It is possible that more is already known than is being put into practice, and the most formidable obstacle to the goal of developing talent may not be lack of knowledge but how to apply knowledge, using existing structures.

Congress is presently appropriating monies for the development of scientific curricula because representatives are persuaded that the country is seriously threatened by external competition and the poor quality of education which will shape our manpower resources for the next generation. Congressional representatives want research and knowledge to be used to improve the quality of education, but intervening in the educational system poses real problems. The system is large, deteriorating and in need of repair; the strength of the American public school system is its diversity, a quality jealously guarded at the local level.

The educational system, in terms of the development of scientific talent, may be thought of as a net which captures at grade one 100 percent of all available talent, but by the end of four years of high school, only 75 percent of the initial population finishes high school, 25 percent of the population has already dropped out.

The future society will need a full technological infrastructure, not just a cadre of scientific elites, including:

1. An educated populace that can read the newspaper.
2. A managerial decision-making cadre conversant in science and engineering.
3. People appropriately educated to support the technological infrastructure.
4. On the peak of this hierarchy a good supply of gifted and talented people are needed for leadership.

The NSF plans to meet these needs by building a consistent, coherent base of science and mathematics education that spans kindergarten through grade twelve. The goal of the science curriculum is to give students an overview of science, regardless of their eventual role in life. The curriculum will be designed to prepare all students for college level science as well as to provide some level of scientific literacy for the 50 percent of the population who are going to conclude their science education at high school.

A third discussion of federal policy focused on funding policies from the bottom up perspective, taking Minnesota as the point of reference. This perspective helped illuminate the political dispositions and structural needs of educators in the state and local school systems.

A point made previously was reiterated here: that federal intrusion into local education is not welcome. Educators at the local level direct their loyalties to the voter and are less responsive to distant federal proclamations. State and local officials of a sample state school system uniformly support the new system for administering Chapter 2 block grants, for example, because they feel that it requires less paperwork and affords greater freedom to use funds creatively. The net effect of this assessment is that less intrusion is equated with better education. Unfortunately, the changes in the Chapter 2 block grants are likely to increase the difficulty of obtaining funds for mathematics or gifted and talented programs.

In general, federal funding generates recurring problems at the local level. To begin with, federal monies are viewed from the local perspective as being small in comparison to local monies; the timing of federal funding creates of problems, as well. The political vying that attends Congressional appropriations makes funds available on short notice and for only short time periods. More clearly marked priorities and a full year planning/funding cycle would assist school districts in making better use of funds. Other weaknesses in science and mathematics education are poor textbooks and underprepared teachers.

In regard to highly gifted students, it appears that public schools can serve only in densely populated areas. Multidistrict pullout programs offer alternative models for gathering enough students to form classes of adequate size and have the advantage of being less expensive than residential programs. Despite these limitations Americans appear, overall to have developed a very humane educational environment. Care should be taken not to destroy this quality while implementing more academically challenging programs.

Scholar/Practitioner Networks

The discussion of scholar/practitioner networks focused on the structural and evaluative qualities required for successful networks and emphasized the problems and benefits that arise when attempts are made to apply results of research to the practice of education. The major topic was the efforts to establish the procedures and structures promoting collaboration in research and policymaking for the Government-University-Industry Research Roundtable (GUIRR). The GUIRR, in recent policy formulation, signaled the development and retention of science and engineering talent as the most critical issue in the practice of science. The results of a Roundtable symposium show that, generally, students are choosing utilitarian degrees and demonstrating declining interest in undergraduate and graduate study of the physical sciences. Even the most highly qualified students are included in these trends, but an additional and worrisome concern is connected to projected decline in the number of twenty-two year olds. The size of this cohort is anticipated to decline by more than 25 percent by the year 2000.

An unsettling characteristic of discussions of the scientific manpower needs of the nation is that the data are not conclusive. The flow of scientific talent is critical to scientific and engineering advances. It is therefore crucial to understand the factors that influence students to elect careers in science and research. The development of high quality scholar/practitioner networks is an important means of concurrently evaluating the status of this potential crisis and of testing possible solutions. The list of principles for establishing functioning networks is based on observing a wide range of programs, a large part of whose work includes some kind of networking. A successful network must:

1. Involve the best scholars and practitioners to evidence the legitimacy of the activity.

2. Involve senior officials who have the authority make policy.

3. Address issues which are intellectually challenging to participants and in the interest of the institutions they represent. Uneven distribution of organizational self-interest results in exploitation of one group by another; even distribution of self-interest results in collaboration to solve a problem of high priority.

4. Establish short and long term objectives.

5. Have sufficient financial and staff support.

6. Be flexible in its ability to respond to the demands and opportunities of various participants.

7. Focus attention on the core participants and the problems they have chosen to address.

8. Be sponsored by organizations which are neutral with regard to network goals, problems and solutions; the sponsoring agency or agencies must be credible to the network members.

Networks may be formed at the local, state or national level. Examples of networks concerned with the issues of the conference, i.e., educating the academically talented in science, mathematics and engineering, include the Mathematical Sciences Education Board (MSEB), and the Ford Foundation Urban Mathematics Collaboratives.

By observing the criteria outlined above, it may be possible to promote the development of a network which can communicate the respective needs and contributions of scholars and practitioners whose expertise bears on the issue of improving scientific, mathematical, and technological education for our nation's most gifted youth.

The response to this formal presentation shifted the focus to a more fundamental aspect of networking, that networks could be established to develop talent in the targeted fields. The discussion of the required aspects of a network and the examples of successful networks give rise to the question of what kinds of structures promote the "culture of science." This discussion, especially in its emphasis on curiosity, echoed the concerns of the keynote address. The communication of the culture of science, including mathematics, is essential to developing talent in these areas. The nature of this culture is a belief structure that places the highest value on curiosity. Thus, the posing of "the good question" is of a higher priority than having all the answers. Other highly valued qualities contribute to the posing of the good question. First among these is the interplay between imagination and reality. Fantasy and imagination are the sources of scientific descriptions, theories and other conceptual insights, when they are linked to logical reasoning and empirical testing. The quality of veracity is another important value in the scientific culture. Being able to see data for what they are, and being able to rely on the validity of another's data crucial to the practice of science. A value arising as a consequence of these tenets is the legitimacy of error. The method of trial and error is central to testing descriptions and theories, and error is an important source of knowledge, as the practice of science provides that we learn from our mistakes. The last attribute of the culture of science, which is supported by the other values, is that of replacing beliefs with persuasion rather than coercion.

This culture, taken as a whole, supports one of the most important of human enterprises, that of inventing new axioms and creating knowledge. The enterprise of enlisting students' interest and excitement in the study of mathematics and science affords the opportunity to *make* mathematics and science, rather than just to acquire facts. This is especially important with academically talented youth who are likely to be the mathematicians and scientists of the future.

One practical way in which the NSF is helping to promote the development of talent, as well as the development of scholar/practitioner networks, is the Young Scholars Program. Key aspects of the activities, again, recall the themes of the keynote address:

1. The exercise of natural curiosity is one of the best ways to learn science.
2. Students should be exposed to environments that promote interest and experience in problem solving and research methods.
3. Activities should achieve a balance among lecture, laboratory, field and research, should be interdisciplinary, and should promote interaction between experts and students.

The current level of funding at a little over $3.5 million is likely to double to $7 million with the approval of Congress. This program provides the opportunity for networking between practitioners at university research laboratories, field stations, and industrial and government laboratories and our best students.

The second respondant to the presentation on networking spoke to the question of improving science education by observing that because of what highly talented people potentially can do to improve the human condition, the nourishment and preservation of their talent is a matter of great importance. Although people with other specialties may make equal contributions, the support of those with skills in science and mathematics is particularly urgent in this age of high technology. One measure of success in the achievement of this goal is the number of people who receive the doctoral degree in some branch of science and mathematics.

Over the last twenty years, in American universities there has been a general increase in the number of individuals who receive their Ph.D.'s in science. For a moment one might conclude that we are doing very well. Details of the data reveal, however, that there are reasons to draw conclusions with caution. The number of Ph.D.'s in the physical sciences has declined while Ph.D.'s in engineering have increased. Similarly, the number of Ph.D.'s in research and academic psychology has decreased while those in health services have increased by about a factor of three.

The reason for these changes is primarily economic. Students are entering fields that are practical, well paid and available, resulting in an insufficiency of qualified students in some crucial areas. Another factor keeping students out of science and mathematics majors is inadequate preparation. Many college students find out when they take their first course in science that they lack the skills that are taken as assumed prerequisites.

Structures called "scholar/practitioner networks" have been created to deal with the shortcomings of science education in America. These networks, comprised of people committed to science education, able to work together, and possessed of appropriate expertise, undertake a wide range of activities and support a wide variety of projects aimed at improving the situation of science in our country. They encourage research, support symposia and workshops, offer fellowships and internships, establish policy and priorities, and facilitate communication through meetings and publications.

As short-term goals, these accomplishments are to be applauded. It is unclear, however, whether there is any enduring impact on the problem at its source, the reluctance of society to provide adequate support for scientific education and research.

Summary

Among the themes touched upon in the discussion of policy perhaps the most striking is the similarity in the profile of problems, possible solutions and research issues between the Federal Republic of Germany and the United States. A dearth of scientific and technological talent is anticipated for both nations by the year 2000; the related issue of maintaining an existing high standard of living lends impetus to the search for solutions. Two strategies endorsed by representatives of both countries were the nurturing of talent through special educational program and further research on the reasons for low participation of females in the fields of mathematics and science. Contributors to the discussion of policy in the U.S. spoke in detail to the problems and possible solutions to the nurturance of talent. Top down interventions from federal to state or local levels tend to come in the form of funding from legislative and federal agency sources.

The needs of traditionally underserved groups--females, minorities, and economically disadvantaged groups--are receiving special attention in the program priorities of the NSF and in current legislation. Emphasis at the NSF on the recruitment of females and minorities is based on the belief that these groups will contribute the largest proportion of talent in the next decade. Legislation for other minorities, such as the handicapped, also is inspired by the desire to assist neglected groups and individuals in the fulfillment of their potential.

The problem of improving the quality of science and mathematics curricula includes not only changing the curricula, but retraining teachers, reformulating policies that are more realistic about demands made on teachers, and involving scholars and practitioners in networks that facilitate communication about discipline-related problems and research developments. Involving teacher/practitioners in dialogue with other experts keeps the lines of communication open between scientist/scholars and the classroom, and stimulates a more challenging atmosphere for both teacher and student. While there was some consensus among the speakers that simply increasing funds for the gifted education would not automatically increase the quality of graduates in mathematics and science, there was also recognition that the quality of students entering these fields was related to the level of remuneration available to graduates in the targeted disciplines. The discussion of policy reinforced the perspective that efforts integrating systems are necessary for the delivery of a satisfactory level of educational services for gifted children.

Programs to Nurture the Talent of Children

The variety of programs described throughout the conference reflected the position held by most participants, that there is no single program format which will meet the needs of all gifted students. Even though programs may share similar goals, the diversity among the population of gifted students requires the development and support of a wide range of programs.

Questions of how to provide programming for gifted students were approached from three different perspectives. The first perspective described how meaningful, differentiated programs for gifted students are created, the second, ways in which curricula could be designed to meet the special needs of gifted students. The third perspective described programs designed to increase the representation of minority students among the gifted.

Differentiated Programming for Gifted Students

The presentation by William Durden, Director of the Center for the Advancement of Academically Talented Youth (CTY), emphasized two points, the importance of a central belief system to program development and the use of four basic components to create a program for gifted students. Stephanie Marshall, Director of the Illinois Mathematics and Science Academy (IMSA), discussed these two points, as well as the processes of faculty selection and of securing public support.

The talent search concept originated at The Johns Hopkins University with the Study of Mathematically Precocious Youth (SMPY). Founded in 1968, the steady growth of the program led to its division into two parts, the SMPY program for highly mathematically gifted students and CTY, which caters to gifted seventh graders with either high quantitiative or verbal ability.

The policy statements established for CTY are based on a belief system advocating supplemental programming for gifted and talented students. The belief system represents a philosophical attitude about the nature of talent and provides an operational definition of the kind of talent that the program identifies and nurtures. The three major policies are:

1. *General policy*: The function of the CTY program is to assist in the development of maturing talent;

2. *Identification policy:* The operational definition of the population includes academically talented students with above-average verbal and mathematical aptitude;

3. *Programming policy:* Enrichment and acceleration must be combined in academic programs; assessing prior knowledge and relative improvement is critical to providing programming at an appropriate level.

CTY provides academically talented students with individualized instruction at an appropriate pace, usually in a summer program that allows students to focus intensely on one subject. IMSA also advocates individualized instruction and pacing but emphasizes discovery as the catalyst of learning. The IMSA program is based on a laboratory-oriented, experiential model of teaching and learning, with an emphasis on interdisciplinary and integrative studies.

In combination, the programs described by Durden and Marshall provided a framework for many programs for talented student; but both acknowledged the importance of the same components as the cornerstone of their programs:

1. A rigorous academic program.

2. Affiliation with a university.

3. Curricula based on a combination of acceleration and enrichment.

4. A residential component.

5. Highly qualified and motivated staff.

6. A research component.

This broad framework provides flexibility to match curriculum and program goals to the group of students the respective programs seek to serve.

Curriculum for Talented Students

A sound program design is only the beginning in providing a meaningful education for talented students. A curriculum is needed to meet the specific needs of this unique group. Rather than describing the scaffolding of an existing program, Dr. Kevin Bartkovitch concentrated on the content within the structure, especially on student motivation. Building and sustaining student motivation is key to creating productive scientists and mathematicians.

Bartkovitch identified three ways to develop and maintain motivation among talented students: interesting content, appropriate rate of instruction, and strong peer networks. Course content should be dynamic and interesting, providing students with intellectual challenge. Students need to be provided with problems requiring sustained effort; information should be used to synthesize and integrate a wide range of knowledge. Adapting instruction to talented students involves a combination of acceleration and enrichment teaching.

Instructors of gifted students should have a knowledge base which extends beyond the scope of the current course so that they are capable of answering complex questions. Good teachers are characterized by a willingness to admit their own ignorance, and by the ability to combine this quality with a desire to learn. In addition, good teachers are characterized by a willingness to be flexible to the students' needs, allowing for the exploration of student interests independent of the course content.

The second way to enhance motivation is to provide instruction at an appropriate rate. Gifted students are quick to acquire facts; they need less time than their peers to assimilate discrete pieces of information. By presenting talented students with material which requires engagement, either through novelty of content or difficulty level, students maintain an active relationship with learning. However, providing appropriately paced materials for students with differing ability levels requires time and hard work. Regular classroom teachers need support for their efforts to provide appropriately paced instruction for students, especially as this generally entails extraordinary efforts to locate materials which are challenging to bright students.

The third key to generating motivation is the development of a strong network of intellectual peers. Developing contacts among bright students stimulates motivation in two ways: through forming friendships with peers with like interests, and through creating a challenging and competitive academic environment. Students are motivated when they find friends whose interests and abilities justify and validate their own; the presence of intellectual peers can challenge students to enlarge the scope of their own potential. When faced with a situation in which they are not automatically the best or the smartest, these students can become motivated to excel on the same level as their equally bright friends. Peer networks can form almost instantaneously and often last a lifetime.

Each of the two respondents to this presentation focused on a specific topic: Burton Stuart focused on finding appropriate levels of instruction; Solomon Garfunkel, on using interesting materials to stimulate motivation for learning.

Recognizing that the greater proportion of accelerated students are successful in advanced classes, Stuart pointed to a number of students for whom acceleration decreased, rather than increased, interest in mathematics. Overplacement of students in the study of mathematics may cause frustration from the inability to keep pace with the class. This, in turn, may actually inhibit further study in the subject. A major contributor to the overplacement of students in mathematics is the early identification of mathematics talent. Students who perform well in arithmetic in the sixth grade may not be as capable in higher levels of mathematics, which requires different cognitive skills. One possible solution may be that mathematics talent be identified only after higher level mathematics is introduced into the curriculum.

Two other problems were discussed in this response: poor mathematics education in elementary school and insufficient parent involvement. Elementary school mathematics education is deficient in part because of poor teacher preparation and unnecessarily slow curricula. Elementary school mathematics and science teachers often lack both expertise and motivation. The lack of competence inevitably has a detrimental effect on the interest level of students. The pace of instruction is slow, because of poor teacher preparation and teachers' low expectations of elementary-aged students' abilities. This slow pace contributes to the learning gap observed between students in the United States and other countries.

As the second respondent to Bartkovitch, Garfunkel discussed the topic of stimulating motivation through the use of engaging materials. He suggested that if material is presented in an interesting manner, students will be motivated to continue to study the subject. Interest in mathematics can be enhanced by providing students with engaging problems which incorporate real life situations that are fun, exciting, and open-ended. These problems, besides capturing students' interest, can bring enjoyment and motivation to the teacher. Mathematics problems presented to gifted students are best when they are structured to be approached from several directions. Problems requiring synthesis of information from different fields are also desirable, as they reflect the numerous uses of mathematics in many subjects.

The presenters on the subject of curriculum for gifted students emphasized the need to move away from pedantic and didactic instruction for students talented in mathematics, science and technology, and toward curricula that are creative and flexible. Although curricula, like programs, need to be tailored to the learning situation, certain elements must be incorporated. These are scope and challenge in the structure of the curriculum, active exploration of material, and problems which represent real world occurrences rather than artificial applications. Preferably, the solution of these problems will require a synthesis of information from diverse disciplines.

The curriculum will be best presented by teachers who are well qualified, who are themselves engaged in life-long learning, and whose level of expertise extends beyond the scope of the specific curriculum. Providing support for these teachers is essential. Both time and money are needed to enable teachers to search out materials which could extend and expand the regular curriculum for the gifted child. These materials are especially important for students who have advanced beyond their classmates and yet are not prepared to accelerate to a higher level. Through the use of these techniques, the curiosity which is so important to later productivity can be maintained and enhanced, helping to ensure the involvement of these students in careers which involve mathematics, science and technology.

Increasing Minority Representation among Talented Students

Programs such as CTY and IMSA are successful in providing programming for students with demonstrated talent; however, several conference participants (e.g., Tressel and Malcolm) reported that the nation's talent pool is changing. Females and minorities will in the future make up a large part of the nation's work force. Unless the representation of these groups among talented students also increases, the resource of talent available to the country will decrease. Both females and minorities are currently underrepresented among mathematicians, scientists and engineers. Therefore, students from these groups need encouragement, training, and opportunities to allow their talents to flourish. Part of the problem of underrepresented students could be solved through active recruitment of already qualified minority students. Another question is how to reach talented students whose environment suppresses the full expression of talent. One productive area of research maybe to investigate the characteristics of students who overcome adverse environmental circumstances and achieve at a level comparable to their more fortunate peers.

Judith Griffin, President of A Better Chance, Inc. (ABC), spoke about the mission of the ABC program, to "substantially increase the number of well-educated minority people who can assume positions of responsibility and leadership in American society." The program is dedicated to increasing the representation of minorities, especially black students, among the nation's professionals. The success of the program has made it a resource for others interested in increasing the participation of minority students in programs for talented youth.

Minority students face a myriad of barriers as they enter the educational arena: the problem of low socioeconomic status is often compounded by inadequate financial aid, peer pressure against academic achievement, the lack of advocacy or active recruitment by school faculty, and low expectations for achievement. The combined result of these and other barriers is inappropriately low scores on standardized achievement tests, regardless of potential ability.

Several aspects of ABC's program distinguish it from other efforts to recruit minorities. One of the unique components is the active participation of member schools, a consortium of independent college preparatory schools committed to providing education to talented minority students. Combining the identification of talent and placement with cooperating schools provides a coherent effort which forms the basis of the success of the ABC program.

Part of ABC's mission is to find alternative methods of identifying talent. Analyses demonstrate how their selection criteria are related to later success. The comprehensive assessments made by the ABC staff, which combine recommendations and student test scores, were the best predictors of later success in programs. Standardized test scores alone were the weakest predictors. Other studies have indicated that ABC alumni are as likely to select careers in mathematics and science as students in the general population, a proportion substantially larger than usually found among minority students. Results of surveys of the alumni of the ABC program indicate that the basic premises of the program are correct: through the use of alternative identification procedures and with appropriate support, minorities can succeed at the most rigorous levels of American education.

The second response, by Belvin Williams, focused on the problems encountered when using a standardized test as the primary means of identifying talent. Williams cited several reasons why standardized test scores may be suspect:

1. Although a high score on an achievement test indicates potential success in college, the meaning of a low score is not clear: low scores on achievement tests do not indicate "no aptitude."

2. Achievement tests measure only a limited range of the cognitive skills considered necessary for success in college.

3. Several sources of measurement error enter into the accuracy of prediction of test scores, including error in test construction and in the criteria selected as the operational definition of talent.

4. The assumption that the statistical function relating test scores and other criteria of talent is linear may be false. The statistical relationship between test, criteria, and success could take many forms, and is unlikely to be as clear-cut as suggested by the use of linear functions.

Williams also addressed the issue of how to increase the representation of minorities in the talent pool. Even though existing programs have very few false positives among their minority recruits, an overwhelmingly large number of false negatives occurs among the minority population--many students are not admitted into special programs even though they are capable of success. The question this problem raises is how to find a cost effective and efficient means to broaden the scope of the admissions process. The success of the ABC program suggests that minority students achieve best when they are associated with an adult who believes in their capacity to excel. The inclusion of teacher recommendations as a means of identifying students with exceptional ability may be an effective means of locating talented students and alerting teachers to the possibility that there may be talented students in their classes.

Maxine Bleich described an effort similar to that of ABC, but funded by the Josiah Macy Foundation. The Macy Foundation sponsors several support systems designed to encourage minority participation in the study of medicine, including establishing Offices of Minority Affairs in over half of the nation's medical schools and supporting excellence in traditionally black undergraduate schools. In 1980 the Foundation implemented the Minorities in Medicine program in secondary schools. At the program's inception the Foundation planned to select project schools in which exemplary academic programs would be developed. The focus of the programs would be to provide minority students with an excellent overall academic background, with a particular view to later involvement with medicine. The Macy Foundation provided the funds to establish high quality, academically rigorous education in the impoverished neighborhoods using a traditional educational format: four years each of mathematics, science, social studies, and language arts. Students received training in study skills prior to entering the program. After several years, program evaluations indicate broad-based success. Not only have students progressed academically beyond expectations, but teachers' and administrators' expectations of their students have improved.

Procedures especially effective for the ABC program included the use of teacher and counselor recommendations and personality characteristics of the students. Again, the importance of the study of characteristics unique to gifted students becomes apparent. The concept of combining standardized achievement measures with personality characteristics to identify talent was prevalent among conference presenters. Sherburne presented data indicating that only a subset of academic achievers become creative producers; Perkins spoke on the importance of precursor abilities on later achievement; Zigler emphasized the unique personality characteristics which contribute to the presence of giftedness. To increase the pool of talented adults entering the work force, programs for gifted students will have to incorporate some of these methods of identifying talented students.

Summary

Developing programs for talented students requires tailoring programs to students' needs. Although all programs are different, certain characteristics are common to all. A belief system, or program philosophy, provides a cornerstone upon which all other programming decisions are made. All of the programs described at the conference support flexible and individualized programming for talented students. Beyond this, each subscribes to a different belief system which sets the respective goals and priorities.

These different, though not mutually exclusive kinds of programs include:

1. Providing rigorous supplementary programs for students;
2. Providing experiential education; and
3. Supporting talented minorities in their drive for quality education.

Contributors to the discussion of program emphasized that an effective program needs a dynamic and interesting curriculum to stimulate the curiosity of students; a good curriculum provides information which is engaging, relevant, and open-ended; the process of problem finding should be emphasized along with problem solving. Real experiences either in laboratories or in real working environments add to classroom learning. Most importantly, talented students need teachers who are well trained, engaged in learning, and sympathetic to the characteristics of talented students.

The primary goals of any program for the gifted is essentially the same--to provide quality education for talented students and to create an intelligent and productive adult. The programs presented at this conference far from exhaust the number of quality programs currently engaged in the endeavor to fulfill the potential of talented students. Continuing to develop creative and diverse programs is the way educator scholars and practicioners will be able to meet the needs of any population of talented students.

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DEVELOPING ACADEMIC TALENT: A PROBLEM OF VERTICAL INTEGRATION

Alvin W. Trivelpiece

I know that most of you had your material prepared and written some time ago. I did not. Between regular responsibilities, the nightmare of remodeling an apartment, and arranging an event with the President on this Wednesday, I got a little behind.

So yesterday, as I was beginning to prepare what I might say here today, I realized: first, that since it was Sunday and I wasn't out jogging, I had taken on too many commitments; second, that education is still a very personal matter even though it is highly institutionalized; and third, that science and technology education is being discovered by everyone. Yes, folks, everyone. Even the physicians have come to the conclusion that there is a problem with science and technology education. They want to help. On the personal aspects I am going to draw on some of my own experiences. It may be a little bit different from the points you normally hear, and if they raise some discussion and controversy, so much the better.

Stockton, California, where I was born in the 1930's was not what I would refer to as a hot bed of scientific research where contact with scientists or engineers of any kind was possible. There were no role models, no enrichment programs, nothing. But, there were batteries, switches, pieces of wire, ignition coils from Model T-Fords, old radio sets, my grandfather's saw filing shop, Model-A Fords to take apart, shop courses beginning in the fifth or sixth grade where it was possible to learn to solder, operate a lathe, make a breadboard, and so on. In short, as far back as I can remember, there was a virtually limitless supply of things to take apart, build, repair, modify, improve, etc. As it turned out, I went on to pursue a career in experimental and theoretical physics.

Surprisingly, the things that were to prove to be most valuable to me were not the courses in algebra, geometry, trigonometry (which I had to take as a correspondence course), or chemistry (which wasn't available) or physics (which was), but rather they were the shop and vocational training courses. Now I know that to some in the education business this is heresy, but in my case it is true. What I regard as the most important feature of why I became a Physicist was that I was curious (perhaps inquisitive is a better term since some believe I still am a bit curious) and that there were countless objects on which I could inflict my curiosity. Most of these objects never worked again, but I learned how they worked, and more important, I learned how to figure out how they worked. The shop courses gave me the skills to design and make much of the complex apparatus of advanced experimental physics research. In my own research in Plasma Physics, I used this practical knowledge as much and maybe even more than my knowledge of Newton's Laws, Maxwell's Equations, and Quantum Mechanics.

As a professor of Physics, I used to be appalled at what I called the kinesthetic illiteracy of some of the graduate students who did their advanced degree work under my supervision. Some of them didn't know which end of a soldering iron to pick up. How can you be an effective scientist with such a disability? I know that some of the contemporary thinking in educational circles has it that you can learn these things quickly once you have the theoretical principles well in mind. Maybe so. But I question this conclusion and, besides, where do you learn curiosity? How is it taught? I claim that the only time in your life that you are ever a true intellectual is when you can afford to ask a question without giving any serious concern as to whether the answer is important to you in your ability to make more money or pass a course. When is that time? Every parent knows. It is when they are subjected to that endless sequence of "why" questions. Why is the sky blue? Will I run out of words? How many words do I have in me? I'm sure that you know hundreds of such questions.

My question is: What happens to that curiosity after a few years in elementary school? Does it decay in some of us naturally? Is it brutally beaten out of us by a system that seeks to impose social conformity on us? I am sure that I don't know, and I suspect that there is no good or simple answer.

In the case of my own children, who had the good fortune to go to otherwise excellent elementary and secondary schools near Washington, DC, I was appalled to learn that there were no shop courses for them in their schools, and worse, our nice new suburban home lacked a generation of junk to take apart. It's not, that there were not the kind of courses that I took, which made it possible to become a Journeyman Electrician the year after I was out of high school, but it was much worse. There were no lathes, no shapers, no soldering irons; nothing to speak of. As a result, I did things to compensate for this oversight of the School Board. I built a shop in my basement for Electronics, Chemistry, Woodworking, and general messing around. I did this so that my children would not be as disadvantaged as some of the students that I saw in the University in terms of simple technical skills and basic curiosity. In addition, I took two of my three sons over to the student shop at the University of Maryland on Saturdays and had them do projects that allowed them to gain experience in the use of most standard shop tools. This was the naural time for them to learn these skills and they weren't big on regular school courses anyway. They both ended up getting degrees in Physics, and now have their own computer hardware and software company out in California. No they didn't go on to get advanced degrees and pursue academic careers. Was I disappointed? Yes, slightly. But their choice was driven more by their economics goals rather than by any lack of curiosity.

What is the point here? To brag about the fact that my kids made it through college. No. Although it was nice to get them off the family dole. I believe the point here is that, as a result of our collective effort to stress academic achievement and a concentration on college preparatory courses that have little or no hands-on experience that involves building things or taking them apart to see how they run, we may have created conditions where learning has become just a tad boring. Curiosity is certainly not encouraged by the present system and is maybe even being stifled by excessive attention to "book learning" to the exclusion of developing some technical skills. I look around today and I ask, "where are the equivalent kind of things that were available to me in school and around the places where I lived?" I don't find them.

I believe that, even with my efforts to compensate for the lack of certain experiences for my own children, they had a deprived childhood compared to my own in terms of things to play with. Have you taken an alarm clock apart lately? What did you find? Gears, knobs and springs? No. You found a microchip, some leads, and a battery. Try to learn something from that other than not to do it again. Try to figure out the ignition system in your car. Again a computer with some microchips. Your compact disc player is the same way. Take your camera apart and you'll find a computer. And worse, in order to take a frog apart in some places you have to use a computer instead of a frog.

To be sure, education is learning, discipline, social training, and exposure to many different subjects, but I believe it should also be fun in a way that encourages certain aspects of that natural curiosity that young children have. Can we do this? Who knows? Should we try? I believe that we should. Why? Because if we lose them at the age of 3 or 4 or 5, it is just as serious as if we lose them in the seventh or eleventh grades. I may be wrong, but I don't believe that it is possible to recapture the natural curiosity of children in a way that is going to get them back into the flow in high school in the numbers needed by our universities as the raw material for training or as future scientists, engineers, or faculty members. So I believe that efforts to encourage students to pursue careers in science and technology in the 8th or 9th grades are important and shouldn't be minimized, but if they didn't get them on the curiosity bandwagon earlier, forget it.

The Navy is concerned that in a few years the level of education of high school graduates is going to be inadequate to operate our current modern high tech ships, planes and submarines, let alone the future. Industry also has a great stake in this matter. The factory of today is already quite complex technically and the factory of tomorrow will be even more so. Where will the needed work force come from?

The fact that this problem is so pervasive is why I believe that we need to look at the entire system and examine it from a vertical integration or a systems engineering point of view. The Universities complain that the high schools don't prepare the kids for physics or whatever you like. I used to sing that chorus. The high schools in turn complain about the job the elementary schools do. This puts the blame on the kindergarten teacher or pre-school teacher, and so on down the line; or as Shirley Malcolm explains it, the grandmother tells her daughter, "Don't blame me for the way your kid is turning out. I told you that bum you were dating had bad genes!"

It's all well and good for us to yell at each other up and down the system, but it doesn't solve the problem. Furthermore, the system is dynamic in ways that need to be understood better if we are to avoid certain classic mistakes. For instance, in the late 60's there was a softening of the job market for scientists and engineers. As a result, a few of them who couldn't get jobs wrote the President and complained. The President fixed the problem by cutting off fellowships for students in technical disciplines. What an exquisite sense of timing he had. This was the time when the supply should have been kept up because there was going to be a shortage later. It was made worse because of the feedback effect which amplified the problem. The system was unstable, that is, the gain was greater than one and the phase shift was 180 degrees. Can you imagine certain industries in the U. S. and overseas relying on vendors to supply goods or services that are vital to their interests and survival without at least attempting to achieve some degree of vertical integration or without understanding the dynamics of flow of materials needed to meet their production requirements?

It seems to me that we go out of our way to avoid understanding these dynamics in education.

It was with these and related matters in mind that the reconstituted *Working Group One* of the Government University, Industry Research Roundtable (GUIRR) began planning to consider this problem from what might be called a systems point of view or one of vertical integration. I know that most of you are familiar with GUIRR, but let me go over some features that it has that might give it an advantage in working on this problem of providing suitable talent for our nation. First of all, GUIRR is unique in that officials from Government can sit down and discuss matters of interest with representatives from Universities and Industry without a priority violating the Federal Advisory Committee Act. Second, GUIRR has no direct ability to do anything. "So why bother to try?". you might ask. Look at the so-called "Florida Experiment" in which some real progress in reducing bureaucratic accretion has been made. This has been accomplished in part by getting the Feds the use of the same boiler plate for all grants and contracts with all of Florida's Universities with the understanding that there will be a corresponding reduction of non-essential reviews by the State and the Universities themselves. One of the reasons this is working is that those who have to live with the changes are implementing them. The experiment is by no means over and its extension to their political subdivisions remains to be accomplished, but even the most cynical among us (by that I mean the OMB) seem to believe that it has good prospects.

Can GUIRR play a similar, useful role in this question of the supply of academic talent, particularly in the areas of science and technology? That is not clear. However, what is clear is that GUIR doesn't have the same vested interest in looking at the problem as some of the other players in the game (i.e. primary, secondary, unions, etc.). What we have done so far has been limited to some organizational meetings to see where we might go with the idea trying to look at the talent problem. We certainly would welcome suggestions.

Lately it seems that everybody is either worrying about or working on some aspect of the education problem. Most of what I have seen involves the question of science and technology education, but I know that the problem is quite pervasive across the board. I don't pretend to be an expert in this subject area, but it seems to me that something useful has gone out of our lives with the almost universal elimination of shop courses or their equivalent along with the inability to take things apart that our modern microchip world has brought us. Now I don't inhabit places like "TOYS R US" as much as I used to when my children were little and maybe my perception is wrong, but I don't see this lack of things to take apart being replaced by toys that might accomplish the same purpose. Namely, in generating a curiosity about the world and how it works, thus stimulating a natural desire to keep going in studies in areas where the going eventually does get a little tough. Maybe there is a market for producing already broken, spring-driven, mechanical alarm clocks.

In closing, I want to point out that in the last few weeks I have attended several meetings on science and technology education. Not surprising, you say, and even overdue. Particularly since every candidate seems to want to be known as the Education President. Actually, what I found surprising was that I believe that I was the only individual invited to all of these separate meetings. To the best of my recollection there was no other overlap. These meetings included one by *USA Today* and ALCOA to discuss their Scope Program and a meeting by the Council on Competitiveness, which plans a paper on this subject for the transition team after the election and some missionary work on the platform content regarding education.

Perhaps the most surprising and most interesting meeting was the one organized by the AMA. As a result of their meeting, there is now a modest effort to explore the possibility of a National Congress on Science and Technology Education in America next March or April in Washington with literally a cast of thousands, including the President as keynote speaker. Will it happen? Who knows, but the AMA is an effective organization once it gets moving and committed. They already have a draft charter for this Congress and a working group to look into the next steps. If you are interested in helping it along, or killing it before it gets going, you might call Bill Hendie at the AMA in Chicago.

I am pleased that there seems to be so much attention to this problem of improved educational conditions for our children. There is no single or simple solution to the problems that we face. But there is a sea of change that gives me hope that improvements can be made. Namely, there is now an element of market pull rather than push in that the consumers of the product of our schools--the doctors, the services, industry--recognize that they are facing a critical supply problem. So I say welcome to the AMA. Maybe the dentists will even get involved. When that happens the problem will be solved quickly--the kids will be told, "Learn science or I will drill your teeth!"

Discussant Reaction:
Developing Academic Talent: A Problem of Vertical Integration

Frances Degen Horowitz

They say that those who do not know history are condemned to repeat it. I am reminded that the last time we seriously talked as a nation about science and math was in the 1950's after the Russians launched Sputnik. The Sputnik event then spawned a whole array of programs in this country that had a considerable impact. The sobering questions we need to ask ourselves are: 1) Why they didn't survive, and 2) Why we're talking about the math and science question again.

Some of you may know a book called *Children of the Dream* written by a psychoanalyst named Bruno Bettleheim of the University of Chicago. When Chicago was torn by riots in the 1960's he decided that one of the models that he wanted to investigate as a possible solutions for Chicago's concern for its children was the kibbutz in Israel. He went to Israel and stayed six weeks and wrote *Children of the Dream*. It was a very controversial book in Israel, but it is a very interesting book. Actually, although he spent only six weeks there, he did capture much of the essence of the kibbutz. But he ultimately came to the realization that the proportion of resources that the kibbutz spent on its children was so far out of line in proportion to the resources that Chicago--or any city in the United States--was prepared to spend on its children, that the kibbutz model of educating its children was not a viable model. That is a very telling conclusion.

I believe that a society is ultimately judged by the commitment of its resources to care for its children and its old people. In the United States we don't fare very well by that measure. Our policies with respect to education in this country are analogous to planting young seedlings and periodically pulling them up by their roots to see how they are doing. One doesn't get a fullsome forest in this way, and our policies with respect to caring about children in this country are mired in conflicting values.

I teach a course at the University of Kansas on developmental theories. At the beginning of that course I give an overview of the history of developmental psychology. One of the stories that I like to tell is the story of the establishment of the Iowa Child Welfare Research Station. It then changed its name to the Institute of Child Behavior and Development but was still known as the Iowa Child Welfare Research Station. It got its name in an interesting way and was established in an interesting way. Just before World War I an Iowa woman named Cora Bussey Hillis conceived of the notion of having a station like an agricultural research station where parents could go and get help raising their children the way farmers went and got help raising their crops. She went to the University of Iowa and she proposed to endow a child welfare research station. The president of the University of Iowa was aghast at the idea because children and universities didn't seem to him to mix very well. He suggested that she might give her money for a bell instead, that would ring out across the campus. Well, this was a very persistent lady, and she went to the legislature and proposed to the governor that the State of Iowa establish a child welfare research station. The transcripts of the debate in the Iowa legislature in those years are very interesting. The issues raised were as follows: What business did the government have intruding in family life? Children are the responsibility of parents, and the State should not be involved in raising children. If this sounds familiar, it could possibly be because we haven't changed all that much. She proposed it and she was turned down, but in 1919 the Iowa Child Welfare Research Station opened.

In 1919 as a result of the United States entering the First World War, the first wholesale evaluation of young men of this country revealed a large number of young men who were physically and mentally unfit to serve in the Armed Forces of the United States. Cora Hillis was able to use that information to say "See, it is the business of the government, it is the business of the nation to care about its children".

We're still arguing today about the intrusion of the government into the family, about what kinds of responsibilities we have toward child care, and about what kinds of meaningful national policies we ought to establish with respect to children and education. Al Trivelpiece asked the question 'When do we lose children?' We lose children when we don't have enough resources, when we don't have enough commitment as a nation to commit resources to care about children, and when we don't have enough commitment to believe that children can learn.

I'm a developmental psychologist. We know a lot about cognitive development, early development, and the kinds of talents that children have that never come to fruition. More talents are lost than are developed in this nation, and that's not something of which we should be proud. What are the dynamics of this?

Al talked about vertical integration. We don't have any vertical integration in education or in educational policy in the United States. We have traditions of local control, of community control of schools, community control of curriculum. These are strong American traditions. In Kansas there has been an argument about qualifications for university enrollment. Kansas is a Populist state by virtue of old traditions. Any student in Kansas who graduates from a Kansas high school has a right to go to one of the state institutions. The University of Kansas, like other universities around the country, is dismayed at the lack of preparation in mathematics, in science, and in foreign languages at the high school level. The Board of Regents proposed a mandatory curriculum in the high schools as a condition for admissions to the State Universities. This would require a modification of the admissions law of Kansas. The proposal was not approved by the legislature. Part of the issue was the willingness of the communities, many of which are small communities, to commit resources to an educational curriculum to include all the necessary courses. Part of the issue was local control over the schools but part of the issue was resources.

This highlights the kind of problems that we face as a nation when we want to take a global, national view about the development of a pool of science talent. We have many programs around the country that foster different kinds of talent. If we, as a nation, actually decided to apply the knowledge that we have gained from the existing programs, we could make major advances in the number of children we could nurture in their talents in science and mathematics. The question is, can we seize the moment now in a better way than we did in the 1950s. Japan has recently become the ideal model. But is Japan really the model for this country? Japan is a more homogeneous nation and it has a very different cultural tradition. The effort to superimpose Japan on the U.S., I believe, is ultimately going to fail, because we cannot take models that are not relevant to our culture, to our traditions, and make them succeed. What we can learn from Japan is to commit our resources to care about the children in order to accomplish things.

The issue for us comes down to whether we are willing to make that kind of commitment and whether we are willing as a nation to say that some things have a national importance that will override some of the local, community control issues. This is a very threatening kind of question to raise, particularly in small communities and in small states. The papers that we are going to hear at this conference are going to raise some very important issues with respect to demographics, with respect to population, with respect to committing resources. While the topic of this conference is primarily aimed at science and math, the challenge is a larger one. It is a matter of committing ourselves to and nurturing the talent of all the children in the nation. If we succeed in that, then the science and math challenge will have been solved. So, it's a much more basic question: Those of us who are concerned about what's happening to our children in this country have to raise the issues that address the kind of nurturing we provide and the effect of providing insufficient resources to educate our children.

Discussant Reaction: Developing Academic Talent: A Problem of Vertical Integration

William Anlyan

Al has covered the waterfront very well. He and I have overlapping roots with the Roundtable group. Let me try to introduce a couple of notions different than those he has already presented.

In most developed and developing countries that I have visited, the government is the sole source of monetary support. I ran into this very firmly at the World Health Organization where they would point out that the Scandinavian countries supported research on parasitic diseases by a multiple factor of ten times the research supported by the US. What people abroad don't appreciate is that the U.S. Government is not the only source of resources in the United States. The impression that everything has to be looked at from the federal government is a mistake. For instance, in parasitic diseases one of the most important sources of support is not in the federal government, but the kind of support that the MacArthur Foundation has made available. This conference cannot look to the federal or state or local governments for solutions. We've got to look at the entire free enterprise system, using foundations and corporations and all the mish-mash that makes up the United States as we look at this problem.

I grew up in the British school system for the first 17 years of my life, in an English Publish school in Alexandria, Egypt. The school was designed to prepare and point students towards Oxford and Cambridge; because of World War II, I ended up at Yale. But there's much to learn from the British public school system in terms of nurturing science and math talent for the future. There's a lot about the structure of the British public school system that can't be stomached by the egalitarian American system, but nevertheless, if we're serious about the nurturing of science and math talent we ought to look at the idea of training some capable people specifically for the university.

The next thing I would like to touch on is what I've run into in contrast with Japan. In Japan people work six days a week. On Sundays, they take their kids to the museums to add to their enrichment. I bring this up because I have the feeling that we've become lazy as a nation; we've become lazier as adults and I hope that this does not spread to our children. If competition with Japan is one of our national goals, in addition to altruism and humanitarianism, we ought to look at what's become of the population of the United States today. I had a big shock when I was making surgical rounds one Thursday afternoon and asked, "Where's the resident Jones today?" "Oh, he's off on a long weekend." I had never heard of residents having long weekends until that point. I'm not saying that we should work a hundred hours a week, but certainly as a nation we have become lazy.

All of the sciences are important in our education system, but the one thing that we've really got to be careful of in the field of medicine is to prepare people who are first rate as scientists and physicians, and who also have a humane touch, communication skills, and consistent day-to-day application of their talents. I don't know how to do this. It can't be done by requiring courses in the humanities in medical school or in preparation for medical school. But it's an area which we must address because, particularly in biomedicine, it is almost as key a factor as the delivery of scientific medicine.

Al has identified the fact that we've got to look at both the genetic background and the environmental background when we study how to nurture scientific talent. I'm not saying that we're going to have the Nobel Prize winner sperm bank or ovae, but certainly the environment and genetics are both important.

I'd like to stop with one of my wilder thoughts. I saw 15 years ago that we were not going to have enough nurses in the future, and that we ought to be looking at developing some other kinds of health professionals. I made the mistake of touting that line about 15 years ago, and I can assure you that I've got a back full of scars as a result of that. But last fall it began to be popular thing for certain foundation heads to begin to espouse, and I kidded some of them saying where were you 15 years ago when I was out there all alone being shot at. But, I feel that if we had an ideal pilot university, unencumbered by state legislators, the way in which to nurture talent coming into a school would be to take the top twenty-five percent of a class who are geniuses, who had clearly demonstrated ability at the 0.1 percentile of any kind of test we could manufacture. I would also take the bottom 25 percent if they had lousy SATs but they were geniuses in music or art or something very special. These students may not test well across the board but they have great potential to do something extremely well. The middle fifty percent would be made up of students who were good and had come from a traditional environment in order to build the base of the people who, for the most part, are going to run this nation in the future. I think that we pay far too much attention to saying, "Last year our SAT average for the freshman class was 1380. This year we're at 1410." We should just take the top 25 percent on the basis of their SATs but also look for people who are nontraditional, at the bottom end of SAT scores. They may be the top of the future in terms of hidden talents.

STUDENT PANEL DISUCSSION

Zerrick Bynum, Geoffrey Davis, Jeanne Nielsen and Nancy Smith
Norman Garmezy, Moderator

I happen to like this task, that is, to introduce to you a group of TIP students and to learn about the role played by experiences in their thinking and their plans and goals for the future. After reflecting on this part of the program, since I was told by the TIP powers that be that I must play master of ceremonies in this important portion of the program, proved to me to be a time of retrospection as I sat last night for three hours in an airplane awaiting the arrival of a crew, whose whereabouts were unknown, we were told, because the saving grace of our time, the computers, were down. Well, it enabled me to read the substantial number of papers that the members of the advisory board received and that reading simply convinced me further that there are forces moving in many ways in this TIP program and in this universe that houses it. Because both represent the search for excellence among young people in this region, a search common to three other programs and three other regions that have come together in this shared exchange on the search resources of the nation's most precious resource namely the intellectually talented youth—a resource that has often been left up to chance discovery with a result that some uncounted numbers not only have not been discovered but the widening possibility that those critical potential assets may have gone unrealized. Last night we heard multiple reports that had been sent out to the board as we became aware of the commendable effort here at TIP to extend the even more intensive search of talented in rural south and contiguous areas and to include minority young people.

Some months ago I read Thomas Jefferson's Virginia Papers written at the close of the 18th Century because I was searching for Jefferson's view on schools, and I found his call for free public education in the United States. The particular phrasing caught my attention. Jefferson wrote that in public education we would find, and here I quote him, "the genius among the poor. And through education and reading, history and languages the nation would provide the strengths against those who might oppose a democratic society."

I think this represents what it is that the TIP program is trying to do, particulary in the rural south and among minorities. It is significant that at this point the research on stress and disadvantage gives us a new orientation looking at adaptation in young people rather than maldevelopment—which was the view of the past—is coming to the core, and so, too, is the concept of protective factors. Those are elements of lives of children that despite risks and disadvantages of various kinds, emerge marked by competence and achievement. Thus is the desire to expand its search to program candidates is to be commended and one can only hope that this conditional program goal will be realized.

Tonight, we hear from four young people. I was given their vitae to read, and I find that in them those early aspects of achievement that typically serve as precursors and predictors of later accomplishments. I will share each vita with you, then provide the students the opportunity to talk about their experiences and plans for the future, or anything else they feel they want to say this evening. If they wish to offer comments on the role played by their TIP experience, so be it. If they decide to bypass it, so be it, too. But all of this will have to be achieved, I am told, within the time allotment of five to ten minutes.

I want to begin in alphabetical order by telling you something about Zerrick Bynum. Zerrick's hometown is Charlotte, North Carolina, he is seventeen years old and is currently a senior in the North Carolina School of Science and Mathematics. Under "special academic interests" he wrote this: "Research in biology: I am testing a revolutionary drug through a model which includes microsurgery and, ultimately, kidney transplants in laboratory rats; secondly, independent study in advanced physics and third, mathematics." Under "academic honors" I read the following: "Selected as one of 1,500 seniors nationwide to be considered for the 1988 Presidential Scholars Program; second, presently a semi-finalist for the AT&T Bell Laboratories Engineering Scholarship Program; third, accepted early action to MIT; fourth, recipient of an Air Force ROTC 4-year scholarship; fifth, recipient of a National Achievement Scholarship." Zerrick has indicated as part of academic history research in Biology, independent studies, mathematics. Under "Engineering and Sciences" in the summer of 1987 he writes: "I took a design class in a contest to determine which structure could hold the most weight, which could hold the same amount and least amount. He has made a cultural trip to Paris, France, in the summer of 1986. And I note here that two of our four people have attended Meyers Park High School. That is particularly interesting, and I know nothing about that high school, but if two or more students come out of that high school it is to be commended."

Hobbies are meeting people and socializing; member of the student government, senior representative of student housing, basketball and, this worried me terribly, martial arts. Don't start up with this man.

Talking about career interests, he underlined, "You may quote me on this. I aspire to become chairman of the board or chief executive officer of a Fortune 500 company, start and own my own corporation, and become a United States senator but not necessarily in that order." It occurs to me that, actually, if you were a little bit older you could be a presidential candidate because they are falling like flies, and its open territory.

Under other interests he writes, "You may ask why I set such high goals for myself. Well, a T-shirt I received from an organization states the following 'He aims low who aims beneath the stars.' I truly believe that whatever I set my mind to do I will be able to achieve it. That is not to say that my major goal in life is to be wealthy, powerful and respected, I would like that, but my major goal will always be to be happy in whatever I am doing, whether I am a vagrant on the street or not and to help people to have the opportunities I have had." It is a great pleasure to introduce you, Zerrick Bynum.

Zerrick Bynum: When I first came and sat down at the table I said I had the distinguished honor of being the youngest person here. I would first like to say thank you to those people who asked me to be part of the panel this evening. Beside being able to meet a lot of interesting and influential people this gave me the opportunity to have a scrumptious meal--one that I wouldn't miss at my school because the school's cafeteria cannot compare to this. It is truly an honor to be asked to be on the student panel here this evening. When I looked down at the schedule for the conference and saw speakers for the American Association for the Advancement of Science, the National Science Foundation, Harvard University, Yale University and, of course I can't forget, Duke University and the Talent

Identification Program, and the numerous other prestigious organization and institutions represented, I thought to myself, "Zerrick, this would be a good chance for you to meet some academic heavyweights."

It was the possibility of this same kind of opportunity that made me decide to apply to and attend the North Carolina School of Science and Mathematics and to take courses in science and math that I wouldn't be able to take in my old high school. I believe that it is this type of initiative that makes an average student an exceptional student and also makes the student whom teachers like to teach. I have been fortunate to have had teachers who were willing to supervise me in taking on special projects and even looking for other out-of-class projects that I might be interested in. The two that come to my mind are my research in biology class and independent study. Through my research biology class I had the opportunity to perform research using drugs that are presently being used on humans. In my project I tested a revolutionary immuno-suppressant. This is a drug that suppresses the immune system so that, hopefully, organ transplant patients would not reject their transplant organ. I have performed surgery on rats and fortunately I have had 100 percent survival rate. I may possibly be the first high school student to perform kidney transplants on rats.

In quite a different field of science, namely physics, I have had to discipline myself to taking independent studies. The class of only four student meets once a week. And there is therefore a lot of responsibility on my part to make sure that I understand the material and have completed the assigned work before class. The class requires the teacher to stay an extra three hours after the regular school day once a week. Without a teacher who was committed to meet with students I would not have been able to undertake this endeavor. One major problem that I noticed before coming to Science and Math is the lack of application of learning material in the classroom through demonstrations and the like. I think this is essential not only because it illustrates what you learn is applicable in the real world, but it also makes learning fun. You can witness when those vague formulas finally come to form. I remember several class demonstrations as helpful and enjoyable. In one physics demonstration, we used the value of the force of gravity, the distance a blow gun was away from the wall, the distance the blow gun dart falls before hitting the wall, to determine the speed of the dart. Also I witnessed fiber optics material tested in class. In Chemistry class, on the other hand, the teacher placed some potassium and sodium in water and, as some of you know, this makes a very interesting reaction in water. Science class also served to apply what students had learned because, as you probably know, things in the real world don't always turn out as you would expect them to.

I rate my educational background, thus far, as exceptional. I am fortunate to have had the opportunity to attend the North Carolina School of Science and Mathematics. I have met so many different people and have established life-long friendships. The atmosphere at Science and Math is one which the most excellent and competition only against yourself. I only hope that one day I will be able to provide other people with the opportunities that I had. My parents have been very supportive of my academic interests. My mother is a junior high school counselor, and my father is an optometrist. They have always encouraged me to do my best, but they fortunately don't push me to the point of burnout. Even before coming to Science and Math my peers were pretty much supportive of my academic interests. Although I was occasionally called "brain" or "nerd" if I set the class curve, it was always in good humor and I never took it personally. I believe it is important or else you begin to question whether you should try to do your best academically.

For you people who are about to fall asleep, I am almost through. I firmly believe you should have confidence in yourself and your abilities. This is not to say that you should boast about what you can do, but you should believe that there are no insurmountable barriers to obtain your goals. As far as my goals, I plan to attend either MIT or Stanford University. And I have found out that I am an AT&T Bell Laboratory Scholar. And I expect to major in Electrical Engineering. After finishing college I hope to work for a major technological corporation for a few years and establish a track record for myself, so that they will hopefully pay for me to go back to school and obtain an MBA. After my long-term goals have been met, I would like to head a major corporation, start my own corporation, and enter politics. I would just like to say thank you for the opportunity of letting me talk to you this evening, and those of you who are not from this area, I'd like to say enjoy your visit, and you have to root for Duke now.

Norman Garmezy: "He who aims low aims beneath the stars." Zerrick, there is an interesting thing, there is a brilliant psychiatrist named John Romano, who chaired the Department of Psychiatry at the University of Rochester, and he wrote a piece called *To Each His Farthest Star.* Recently, there has been a house for the recovering schizophrenics, built in Rochester and called the John Romano House. At Christmas time he was invited by the former mental patients to come and stay as guest of honor for the holiday. They made a cake and on the cake was the phrase, "To each, his farthest star."

Now to Geoff Davis who is at Duke University, a senior majoring in Mathematics and Physics whose special interest is mathematical biology and is currently writing an honor thesis—Modeling Urban\Suburban Spread of Epidemics. His academic honors include National Science Foundation Graduate Fellowship in 1988, and Phi Beta Kappa in 1987. He was Dean's List with Distinction in 1985 and 1986 and Dean's List in 1984 and 1985. His academic history includes, of course, Duke University, but he spent a year in residence at Oxford University at St. Peter's College in 1986-87, was a visiting student there in Math and Physics. He also spent some time in Leningrad in the Soviet Union. He is a graduate of the North Carolina School of Science and Mathematics. He lists his hobbies as camping, currently undergoing staff training in Project Wild, a student-run Outward Bound-type program for incoming Duke freshman. He rowed at Oxford in men's crew. He lists traveling, cycling, and reading as other hobbies. His career interests are applied mathematics research. Geoff has been accepted by NYU, Stanford, University of Chicago and has to make up his mind after visiting these institutions. So, meet Geoff.

Geoff Davis: My predecessor's remarks have left me a bit dumfounded. I have not come with any set remarks. Perhaps that has to do with the fact that I have not listed politics as one of my major goals. I'd like to welcome you all here. What I had planned to do was just go over my educational history and then I am prepared to answer any and all questions you might have about the programs that I attended and the experiences of my education.

I've been in the public school system throughout my secondary school education. I spent kindergarten through fifth grades in the Minneapolis, Minnesota, public schools. I skipped the third grade and went into the fourth grade directly from the second grade. I came to North Carolina and attended the sixth through tenth grades in Wilson, a fairly rural town. I attended the eleventh grade at the School of Science and Math and enrolled in Duke University early. I subsequently received my high school diploma, so that I didn't have to join the ranks of high schools dropouts.

The summer after my eighth grade year I came to Duke to attend the TIP program and took Precalculus. After that I was able to take Calculus at my high school. I came back in the ninth grade and took Physics/Chemistry and came back in the tenth grade and took a Statistics course. After that, I came back and worked as a TA [teacher's assistant] in the Precalculus program. I've since TA'd in Russian and Statistics. Next year, I will either go to graduate school or I am considering taking a year off.

John Conger: What was your reaction to your first interactions with TIP?

Geoff Davis: Well, I'd never really encountered anything quite like it. I'd been to other academic summer programs. The TIP program basically involved a lot of independent study. I'd never been able to work at my own pace with adequate supervision. I sort of kicked into overdrive and was able to finish three years of high school math that summer. It was a very valuable experience. I really had a wonderful time. I really enjoyed the people who were there, especially the fellow students.

Norman Garmezy: Jeanne Nielsen is next, hometown, Birmingham, Alabama, as place of birth. She is a freshman at Duke University, class of '91, majoring in mathematics and indicates as her special academic interests math and psychology. Among her academic honors is her Duke Scholarship. She is a member of the Phi Eta Sigma Freshman Honor Society. Her academic history includes high school in Birmingham at the Resources Learning Center for four years and three summers she attended the TIP program and spent one summer at Duke's Precollege Program. She lists her hobbies as piano, geography and juggling. Career interests are math research. I am very happy to introduce Jeanne Nielsen.

Jeanne Nielsen: I am very happy to be here tonight at the Conference on Academic Talent sponsored by TIP because the TIP program played a very important part in my own educational history. The scary thing is I very nearly didn't come to the summer program. I did very well on the math portion of the SAT in the Talent Search, but I applied to the summer program too late to get into my first choice class. I wasn't really sure I wanted to take anything else. But at the Alabama State Awards ceremony, Dr. Sawyer convinced me to come to the program anyway and take precalculus math. Since then I spent three summers at TIP and one summer at the Precollege Program. In fact, the year I took Precalculus Math, Geoff was my TA. Both programs were very good experiences for me, and I really can't imagine what my life would have been like without them at all.

I've had a very favorable environment for learning all my life. My parents were always very encouraging, especially my mother. I never believed the generalization that men are supposed to be better than women at math or science or whatever, because I was never really exposed to that at home. I always thought my mother was being very independent and doing pretty much whatever she wanted to do. I think I picked up the same attributes. No one ever told me I was supposed to be dumber than guys, so I wasn't. I was always pretty confident I could do just about whatever I wanted to. I've been interested in math for as long as I can remember. Whenever I was little, instead of bedtime stories, I had bedtime math problems. Mom would make up problems for me to do in my head and she tells that I knew intuitively how to do calculations that I had never been taught to do. Interestingly, she also tells me that when I started going to school and going to math fairs, suddenly I couldn't do problems that I had been able to do before, because someone at school told me that I didn't know how to do them yet. But I got over it.

I think I planned to be a math major all my life. TIP was one of the most important factors in my education. As I said, the first time I came to TIP I took Precalculus Math and I finished two years of high school math during the three-week program. This was the first time I had ever really been challenged at my potential for learning at my own rate, and it was very exhilarating. After the first summer I was completely hooked on TIP, and I just kept coming back every year.

My high school was also a major influence on me. There was very little special education in the school system where I went to grade school, so for high school I switched school systems and was enrolled in the Resource Learning Center. This is a small public high school for gifted students. The atmosphere was very conducive to learning. The students had close relationships with the faculty and the faculty knew how to relate to gifted students. I think I had much more rewarding high school career than I would have had in a regular high school.

One of my favorite activities during high school was the math team. I always enjoyed the math contests because they challenged me to be creative in mathematical thinking in a way that I didn't get in the classroom where I just, more or less, did applied mathematics in different ways. But, at the same time I wasn't really sure I could make a career of math because I figured no one was going to pay me to do problems in math just for the pleasure of doing them. So, I started to look elsewhere for a career direction. I had many biology classes during my freshman year of high school. This got me interested in biology. I saw that as having more career potential than math. I didn't think I wanted to be a physician and realized I wouldn't be happy unless I was always learning something, so by the time I graduated from high school I had planned to major in biology and pursue a career in medical research. Still there was something missing. I thought I would probably be interested in the career once I learned more about it and got a degree, and yet when I read about developments in the field and I had to force myself just to get to the end. I wasn't really excited about what it had to say, so I started to wonder if this was the right career for me. When I got to college I realized that professors were more than just teachers--that they spend a lot of their time in research, even in fields like mathematics. Between this realization, a semester in organic chemistry, and a very good calculus class, I decided by the end of the first semester that maybe I could make a career of math and this was really what I wanted to do. So now I am a math major. I plan to get a Ph.D. in math, and become a professor in an institution such as Duke and spend a lot of time in math research which is really what I've wanted to do all along.

Norman Garmezy: I know I shouldn't ask this question but where does the juggling come in?

Jeanne Nielsen: Actually, I just started learning to juggle at the beginning of this semester I have a friend who juggles and that's how I got started.

Norman Garmezy: Nancy Smith, hometown, Charlotte, North Carolina. Place of birth, Bloomington, Delaware. Duke University sophomore majoring in Biomedical Engineering, with special academic interests—physiology, math, and German. Under academic honors appears the following: math awards, science awards, English awards, French, Latin and German awards, math contests, math and German honor society. Junior high and high school honor roll, National Honor Society, selection to the summer program at Davidson College, selection to the North Carolina School of Science and Mathematics, and National Merit Commendation. And this is our second person who has had some experience at Meyers Park Senior High School. She's been an exchange student in Germany one summer and is a graduate of North Carolina School of Science and Mathematics. Among hobbies and special interest are listed: geography; all sports especially volleyball; soccer; basketball; and ice skating. Her career interests are biomedical engineering and research in artificial organs. I am pleased to introduce Ms. Nancy Smith.

Nancy Smith: Hi. Somehow all that sounds more impressive when it's listed all together than the way I usually to think of myself. I am glad to be here tonight. I would like to tell you a little bit about my education and what I think has helped me. As Dr. Garmezy said, I am studying biomedical engineering at Duke. It is a fairly small department and there are not very many women in the engineering portion. My interests have always been in math and science. My father is an engineer and, although I don't consider myself as following in his footsteps, I spent a lot of time with him when I was young, and I have always thought a lot like him, that is, from being around him I learned to think in my approach to problems, in the way an engineer thinks.

As you know, I enrolled at the NCSSM I consider this the most important step in my education because it was the first time I was really challenged on a regular basis, as far as education goes. Prior to that I know I had a fairly good class at home in Charlotte, but I was never challenged to my full potential. At Science and Math I first realized there are things I could have just learned on my own. It was a new experience. Another key experience in my high school year was the summer at Davidson College. It was a program in biology for gifted high school student from my county, and, although that was a much smaller selection area, I was also challenged more than at a normal high school course. My instructor was very good. He had never taught high school students and he taught us just as if we were college students. I think I got a lot more out of the course.

One of the other things I would like to mention that I think helped me a lot was the mentorships I had while I was at Science and Math. The mentorship program at Science and Math is unique. It provides opportunities that a lot of people don't have while they are in high school. I worked at Burroughs Welcome one year, three to four hours, one afternoon a week, doing research with the doctors. I had experiences like Zerrick had with rat surgery and participated firsthand in research going on, and grading papers on the actual experiments that I was helping them perform. Opportunities like that that normal high school student don't have really helped me a lot.

I would like to mention something else about the fact that I am a woman studying engineering. It's not all easy, that's for sure. I was just discussing that informally with some of my co-workers. I have noticed that any discrimination or sense of inferiority that I have seen while studying engineering comes primarily from my faculty, from my advisors, at one point, and not so much from my peers. I think this is really interesting. Although, in one of my classes, I am the only girl and that's no problem. My fellow class members come to me to ask me how to do things; I go to them and ask how to do things. But professors have not quite made that link. You'd be surprised. I had a former advisor who did not believe that women should be engineers. That's another bridge to cross. In regard to my educational background, I would also like to add that I've had a lot of opportunities to advance in mathematics and go to math contests, to advance in science, working in biology and that has been wonderful. But at this point in my life, I am not a well-read person. My knowledge of history, in general, is not good. So now in college I am beginning to spend my electives taking basic political science classes and basic humanities classes to catch up and be a culturally literate person.

If you have any questions, I would be pleased to answer them at this time.

Belvin Williams: Describe the sense you feel from the faculty. Is it a sense of hostility, or is it condescending, or what is it you feel?

Nancy Smith: For the most part, it is a condescending attitude. As I said, my former advisor, who is no longer my advisor, did not believe that women should be engineers. He teaches this class which is very important to my major and has failed a lot of women. A lot of people aren't willing to see what you can learn and what your interests are.

Ed Zigler: How did he transmit that attitude to you?

Nancy Smith: He was my advisor for a year and a half and I never spend more than fifty minutes in his office. He never wanted to talk to me, see me or help me in any way. It was not a common situation.

Belvin Williams: Was he that way with all students?

Nancy Smith: No, not as far as I know. But, like I say, he was a very extreme case.

Belvin Williams: Did he ever communicate it to you verbally?

Nancy Smith: Not directly.

Robert Sawyer: Would you share with this group what your plans are for the summer or what our plans are for you.

Nancy Smith: I am working at TIP this summer in their program that they have just started in Ulm, Germany. They are sending five American students to take Intensive Mathematics in Germany for two weeks at the University of Ulm. I will be acting as their TA and their RA [resident advisor] during their two weeks. I think it will be a great experience.

Norman Garmezy: One can feel such an enormous sense of pride from these young people. I think that the high schools represented, Meyers Park, the Resources Learning Center, and the NCSSM deserve special commendation for the roles they have played in the development of the talent of these very remarkable young people.

THE COGNITIVE ROOTS OF SCIENTIFIC AND MATHEMATICAL ABILITY

David N. Perkins and Rebecca Simmons
Educational Technology Center and Harvard Project Zero

A few years ago, Ted and his father sat at friendly odds across the dining room table, eyeing a last piece of pie. As an adult, his father figured it was appropriate to be as fair as possible. No pulling rank here. So his father said, "I'll cut. You choose whichever half you want. You can choose the bigger half or the smaller half, whatever you feel like."

Ted tilted his head and narrowed his eyes. He was out to score. "If one piece is bigger than the other," he said triumphantly, "it's not *half!*"

Ted had a point. He also had much more insight into what a half was than one might expect. Those familiar with the trials and travails of mathematical education will know that youngsters commonly take a rather lax view of the partitioning of things into fractional parts. They often don't realize the importance of halves or thirds or fourths being of equal size, in order to be true halves, thirds, or fourths in the mathematical sense. It was nice to see that Ted was on top of this matter.

But what is it to be on top of such matters? To put the matter informally, what do you have to have in your head to understand about equal parts in fractions, and about the many other scientific and technical concepts where complexities and subtle distinctions need to be recognized? To put the matter formally, what sorts of cognitive structures and processes mediate mathematical and scientific ability?

There are at least two sides to that question. In part, ability is an achievement. Ted could make the distinction he did because of things he had already learned. In part, then, to ask about the roots of scientific and mathematical ability is to inquire about what cognitive structures and processes people acquire that constitute their understanding and capacity to solve problems in a discipline. Those structures and processes make up what might be called *achieved ability*.

However, to ask about the roots of scientific and mathematical ability is also to inquire about the capacities of people that allow them to reach a certain level of achievement. What sorts of structures and processes are the precursors of a certain level of achievement, or perhaps a certain pace of achievement, which might be fast, or slow, or average in comparison with that of other individuals? To ask this question is to ask about *precursor abilities*, those abilities that lead on to others.

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So what achieved abilities and precursor abilities underlie mathematical and scientific performance? Certainly no comprehensive and definitive answer can be offered here. Indeed, to ask such a question is to engage almost every aspect of a thorough going understanding of mind. But the impossibility of the answer one ideally would like is no barrier to an effort to cast a broad net into the sea of contemporary ideas about cognition, cognitive development, and intelligence, to discover what fish may be caught and how well the catch informs the questions asked.

Part I: Achieved Abilities

The overt signs of scientific and mathematical achievement are obvious enough. At the academic level, the individual knows the subject matters in question and can handle textbook problems with efficiency and some insight. The individual, even as a student, may also exhibit signs of creative work: a new theorem, a new perspective on a physical process, an innovative computational algorithm. In professional life, we look to this individual for more of the same. The individual who has in some broad sense mastered a scientific or mathematical domain should evince signs of that mastery in professional work, perhaps not radical breakthroughs, although such are welcome, of course, but at least productive and insightful application. Recalling Thomas Kuhn's distinction between normal science and scientific revolutions, one would expect, at least, the signs of good scientific practice within a paradigm (Kuhn, 1962).

However, all this is but a surface characterization of achieved ability. To get at the cognitive roots of achieved ability, one has to ask a deeper question: What cognitive structures and processes undergird it? For instance, if an individual proves to be an agile problem solver, what cognitive structures and processes equip that person to be so? We pursue this theme under three headings--expertise, understanding, and problem solving--before turning to the second major issue to be addressed: What precursor cognitive structures and processes pave the way toward mastery of a scientific or mathematical domain?

Expertise

Expert Behavior

Ted's father tells Ted to choose whichever half he wants. Instantly Ted responds, "If one piece is bigger than the other, it's not *half!*" On a small scale and in a limited way, Ted's rapid and apt reaction is a symptom of what contemporary psychology has come to call *expertise*.

In recent years, psychologists have become interested in good performance within domains, such as mathematics, physics, chemistry, or computer programming. They have studied experts, sought to characterize expert behavior, and constructed models of the psychological mechanisms that mediate that behavior. What, then, characterizes expert behavior? Among the most conspicuous attributes are the following:

Quick, recognition-like orientation to the "deep structure" of problems. Studies of chess players have demonstrated that chess masters orient very quickly to the potentials of a chess position, often generating a likely move within a few seconds. Of course, chess masters involved in serious play think through a number of other alternatives with care. But the move first conceived frequently survives the further search as the best candidate (de Groot, 1965; Chase & Simon, 1973).

Similarly, research in the domain of physics shows that experts, when asked to sort physics problems into categories, are able to sort problems quickly according to large functional units that reflect appreciation of the physics concepts that impact on the problem, e.g., forces and energy (Chi, Feltovich, & Glaser, 1981; Larkin, McDermott, Simon, & Simon, 1980b). In contrast, novice physics students tend to break problems down into much smaller, less functional chunks, and are inclined to categorize problems less effectively in terms of the objects specified in the problem, for example pulleys, wheels, or inclined planes.

Likewise, in the field of computer programming, it has been found that expert programmers employ chunks that represent functional units (Adelson, 1981; Ehrlich& Soloway, 1984; Rich, 1981; Shneiderman, 1976). Soloway and colleagues categorize these chunks as programming plans (schemata) and rules of programming discourse that enable the programmer to comprehend programs quickly and efficiently (Ehrlich & Soloway, 1984; Soloway & Ehrlich, 1984).

Excellent memory for typical situations, but not atypical ones. A second trait, characteristic of expert performance, is an extraordinary memory for typical situations, accompanied by normal recall for atypical situations. In the chess studies cited above, master chess players were able on their first attempt to reconstruct with greater than ninty percent accuracy naturally occurring layouts of pieces on a chess board that they had seen for only five seconds. In contrast, weaker players exhibited only a forty percent success rate on their first attempt (deGroot, 1965). However, when the chess pieces were randomly assigned to locations on the board, the master players performed poorly, at roughly the same level as novices.

Building on the evidence of experts' memory for typical situations, Soloway and Ehrlich devised a study in which expert computer programmers were presented with two types of programs: those that were constructed of typical programming plans and others that were executable but did not conform to typical patterns of code (Soloway & Ehrlich, 1984). The programs were presented three times, each time for 20 seconds. On the first trial, subjects were asked to recall as much of the program as possible. On the second and third trials, they were asked either to add to their original recall or to change any part of their recall that they felt was in error.

The results paralleled those from studies of chess. After the first trial, 42 percent of the critical lines in the plan-like programs were recalled, while only 24 percent of the critical lines in the unplan-like programs were recalled. In addition, when programmers were working on unplan-like programs, they first typically incorrectly recalled plan-like answers, and only later changed their answers to match what was actually being shown in the program.

Forward reasoning to solve problems. A third attribute of expert performance is "forward reasoning." In a series of studies with expert and novice physics students, Larkin and colleagues have demonstrated that throughout the solution process experts tend to work "forward," from givens toward unknowns (Larkin, 1982, 1985; Larkin, McDermott, Simon, & Simon, 1980a,b). Principles are invoked when they can be used to find a new quantity. Thus, experts generally start with equations that involve mostly known quantities. Novices, on the other hand, typically work "backward" from the target unknown to the givens, employing a general means-ends strategy applied to stock equations.

The Mechanism of Expertise

Before the research on expertise, it was widely assumed that good performance in a domain reflected general cognitive abilities of some sort. To be sure, the chess master or skilled physicist had considerable knowledge of the domain. But there was not all *that* much knowledge to have: a few concepts, a few rules, a few equations. What made the difference between truly skilled and mediocre performance was thought to be general cognitive abilities of some sort. Perhaps, for example, the chess master benefited from a superb visual memory that allowed "thinking ahead" effectively. Perhaps the physicist benefited from an ability to think via abstract symbol systems such as algebra.

But this picture of expertise does not suit at all the profile of expert behavior sketched above. Why should experts respond so reflexively when one might expect them to reason things out more? Why should experts remember typical domain situations well but not atypical ones, if their performance depended on general cognitive abilities? Why would they not reason backward from solution needs to available information, which seems to be a highly general and straight forward solution strategy?

These puzzles led investigators to posit quite a different picture of the mechanism of expertise. It's been argued that expertise depends upon an extensive knowledge base of domain-specific schemata accessed by a recognition-like process(e.g. Chase & Simon, 1973; Glaser, 1984; Newell & Simon, 1972; Rabinowitz &Glaser, 1985). Cognitive strategies are learned within a particular context such as chess or algebra or computer programming. Thus, for example, in physics a general means-ends strategy is overridden in favor of a more context-specific scientific representation of the problem, one that allows the expert to access major principles relevant to the solution (Larkin, 1985).

Furthermore, research on expertise reveals that an extensive period of time and practice is needed to develop the repertoire indicative of expert performance in a field. Some researchers estimate that to qualify as an expert in a given domain one must accumulate about 50,000 schemata, and that such knowledge generally takes at least 10 years to acquire (Simon, 1980; Hayes, 1981, 1985). Hayes' (1985) investigation of seventy-six famous composers suggests that even gifted individuals in a field require about 10 years of concentrated involvement before they can create significant contributions to their field.

Beyond Expertise: Flexible Thinking

Some researchers have suggested that the notion of a large "compiled" knowledge base offers a sufficient account of good performance in a domain. But there are reasons to be suspicious of this claim *a priori*. The characteristic profile of expert behavior has been built on studies where experts and novices confront problems that are thoroughly typical of the domain in question, "textbook" problems one might say. But what happens when experts confront problems that are not so typical of their domains? Not problems that fall outside the domain, nor even problems that are necessarily very technical, but simply ones more off to the side of conventional practice. The question is certainly relevant, because, after all, it is the job of experts in a domain to go beyond the narrow circle of textbook problems and cope with novel problems.

Some information on this question comes from the work of John Clement, who has investigated how people well-acquainted with physics respond to a typical problems (Clement, 1982; Clement, in press). For instance, one question Clement has employed asks whether a spring of large diameter is more or less springy than one of small diameter, made of the same sized wire, and exactly why. Most people quickly conclude that the spring of large diameter is less springy, but the 'why' is more subtle. Unless you happen to have studied the mechanics of springs beyond the matter of spring constants, you probably do not know. You have to figure it out. The key insight is that the restorative force of springs derives from torsion of the wire, rather than any bending of the wire. Many people with professional level expertise in physics do not achieve this insight.

When experts tackle such untextbookish problems, what happens? According to Clement's research, "Everything" is the not too exaggerated answer. They look to kinesthetic intuitions. They try limiting cases arguments. They make far reaching analogies to other contexts. They try equations to clarify a point. In other words, the neat profile of an expert solving a domain-typical problem disappears, displaced by a wide ranging process where recourse to typical academic domain-specific knowledge is mixed in with all sorts of other recourse to general knowledge and general problem solving strategies.

To the extent that an expert can conduct this encounter with atypical problems well, once might say that the expert manifests "flexible thinking." It's not that the expert's rich domain-specific knowledge base is left behind. It figures constantly in the ongoing process. Rather, the point is that all sorts of other resources are brought to bear. A symbiotic relationship appears between typical expert knowledge and other more removed or more overarching kinds of knowledge.

Flexible thinking, in our view, has a lot to do with *understanding* the domain in question and related domains, as well as understanding one's own capacities. In a broad sense of expertise, one could say that expertise includes any understanding needed. But in a narrow sense of expertise, emphasizing only the reflexive responsiveness to typical problems, it is plain that expertise does not entail understanding. Indeed, a student easily could be an expert textbook problem solver and fall prey to all sorts of misconceptions that betray fundamental misunderstandings. With the point in mind that understanding is not quite the same as expertise, in the narrow sense, we turn to discussing the nature of understanding.

Understanding

Understanding of Mathematics and Science as a Notable Achievement

Understanding of any subject matter is, of course, an achievement to be cherished. However, research over the past two decades on students' understanding of scientific and mathematical concepts has underscored how special and rarely won that achievement is in these technical domains. We refer here to the extensive research on students' science and mathematics misconceptions, which has demonstrated repeatedly that large numbers of learners remain subject to serious misunderstandings of key concepts, even after considerable direct instruction and even after developing significant competency with conventional numerical and algebraic textbook problems. For example, Ted's "It's not *half*!" suggested that Ted had straight what all too many youngsters have bent out of shape: It's common for children asked to divide a picture of a circle or rectangle into fractional parts to divide unevenly, as though the comparative size of the parts mattered naught.

Our agenda in this paper does not require a close review of the literature on misconceptions, but a few highlights are worth mentioning. Much literature in the domain of physics demonstrates that even students who have developed a high degree of technical problem-solving skill in dealing with textbook problems exhibit gross misconceptions when presented with tasks that do not suit the typical equation-cranking approach (Chi, Feltovich, & Glaser, 1981; Chi, Glaser, & Rees, 1982; Clement, 1982; Larkin, McDermott, Simon, & Simon, 1980b; McCloskey, 1983).

As an example, consider the "motion implies force" misconception (Clement, 1983). Clement has collected data showing that many students have a significantly different view of certain features of physics than those of Newtonian physics. When presented with a situation in which a constant force is applied to an object, a trained physicist will think of this as producing a constant acceleration in the same direction as the force. Such thinking acts as a "conceptual primitive" that allows for learning many higher-order principles in physics. However, the novice, working from an intuitive model, structures the situation differently. Proceeding from a phenomenological perspective, the student takes into account that in the real world, where friction is present, it is necessary to push on an object in order to keep it moving. Friction is often not considered by the novice to be a force. As a consequence the belief may persist that continuing motion, even at a constant speed, implies the presence of a continuing force in the same direction, as a necessary cause of motion. Clement notes that the misconception shows up in a variety of problem situations, and commonly persists even after students have completed a course in mechanics.

Such findings as these underscore the point that simply understanding the basic concepts in a scientific or mathematical domain is no mean achievement. Then, what sorts of mental structures constitute such an understanding? A familiar, and important answer from many directions in contemporary psychology says, "mental models."

Mental Models as Structures of Understanding

"Mental models" are commonly proposed as important mediators of understanding (cf. Gentner & Stevens, 1983; Johnson-Laird, 1983). To understand, for instance, equal-sized parts in fractions, Newton's laws, or how a computer works, requires having some sort of mental representation that in a qualitative and often dynamic way symbolizes the circumstances. A case in point is the work on Newtonian microworlds by White and Horwitz (1987). They have developed a computer environment that leads students through a number of experiences with simulated Newtonian motion, aiming to remake students' naive intuitions as well as prompt them to think analytically about the Newtonian world. Use of this microworld has been shown to reduce students' misconceptions.

Another case in point is research by the authors and their colleagues on a "metacourse" for enhancing high school students' understanding of BASIC (Perkins, Schwartz, & Simmons, in press; Schwartz, Niguidula, & Perkins, 1988). The metacourse does not displace the existing curriculum, but aims to provide mental models and problem solving strategies typical programming instruction does not address. A central feature of the metacourse is a mental model called "the data factory," which depicts the computer as a factory with a few "stations," such as the keyboard, the variables area, and the program area, all serviced by an internal homunculus called NAB. The data factory model is presented through posters and an animated computer display.

The data factory model is motivated by the observations that students commonly do not seem to understand what goes on inside the computer and cannot accurately hand-execute programs, and that they often think the computer "understands" the intended functions of variables and programs. The data factory is designed to help with these difficulties by giving students a precise way to envision what happens inside a computer. Even the name NAB was selected to help: NAB is an acronym for "Not Awfully Bright," a point used to emphasize that NAB does not know the purpose of a program or variables, only a few very simple things such as where to find the current value of a variable. The programming metacourse has had considerable success in boosting student achievement in realistic educational settings.

One widely recognized problem with a mental models perspective on understanding is that the notion of a mental model is rather vague, with different authors advancing somewhat different conceptions. Some treat mental models as visual-spatial representations of dynamic systems that a person can "run" mentally (e.g., Young, 1983; de Kleer & Brown, 1983). Another approach is to speak of "frames," structures with place holders for information to be filled in from the particulars of the case at hand, with default values that supply prototypical results when information is missing (Minsky, 1975). Holland, Holyoak, Nisbett, and Thagard (1986) conceive mental models as made of "Q-morphisms," rule structures induced from experience that, even more so than frames, possess a complex default structure.

Certainly some clarification of these alternative construals of mental models would be valuable. However, despite the ambiguity, there are characteristics common to most conceptions of mental models that help in clarifying the nature of understanding. The following features seem particularly important.

Default hierarchy. Mental models typically allow for some kind of default hierarchy, by which default values fill in missing information; sometimes default values even override hard-to-perceive available information. According to Holland, et al. (1986), this helps to explain why misconceptions often persist in the face of extended instruction: Academic accounts are learned as information highly localized to the academic context, and qualitative problems of the sort that elicit misconceptions commonly trigger not the new localized knowledge but old default theories. Thus, for example, students instructed in Newtonian mechanics and given a qualitative problem are likely to default to a naive "impetus" theory of mechanics which predates by many years the academic theory.

Qualitative properties. Mental models often differ from formal treatments such as occur in algebra and physics books in highlighting qualitative characteristics of a phenomenon. While students may learn to wield formulas appropriately, they tend not to see the qualitative implications of the formulas. When faced with a qualitative problem, they often respond in terms of their naive qualitative models. Learners need more sophisticated qualitative models, but education tends not to supply them.

Simulation. Mental models generally allow for some sort of simulation or "running," in order to extrapolate implications of the model. Thus, faced with a qualitative physics problem, a student may imagine what would happen, making a "mental movie" so to speak. The simulation feature is powerful, of course, but only serves when the model that allows it matches the reality. Again, learners need sound mental models.

In sum, the notion of mental models, ambiguous though it is, contains these and other important ideas that draw a contrast with conventional textbook knowledge and help to explain shortfalls of understanding.

Beyond Mental Models: Multilayered Networks of Models

In our view, however, another problem besides the ambiguous nature of mental models plagues this perspective on the nature of understanding. Mental models as usually discussed are models of particular concepts or phenomena --Newton's first law, the behavior of an ideal gas, how a computer works inside, the way recursion occurs, and so on. Yet understanding a topic thoroughly often involves not just mental models for the key constituent concepts but a broader grasp at many levels of the matter at hand.

In an earlier paper, we have attempted to map something of the complexities of understanding scientific and mathematical concepts by defining loosely four layers of understanding (Perkins & Simmons, 1987). Just to know the rule is a matter of the content layer. But also implicated in understanding are layers involving problem solving, the epistemology of the domain, and inquiry. For a brief illustration, we elaborate a contrast between the "content" and "epistemic" frames.

Consider, for example, the idea that the parts indicated by a fraction must be equal. One aspect of understanding this, the content so to speak, is simply to know the rule and see the cases at hand as instantiations of the rule. This might involve the help of an envisioned paradigmatic case of halves, where the dividing line that generates the halves cleaves the object neatly and symmetrically in two.

But the "why" of the rule is another matter. One can easily know the rule without any appreciation for its rationale. *Epistemic* concerns deal not with the content of the ideas and principles of the domain, but rather with rationales--the standards for justification of the claims, procedures, and knowledge systems within the domain. Thus, in the case of the equal parts rule, one's epistemic deliberations lead one to ask about the nature of the content. Where would we be with fractions, for example, if one could willy-nilly pick whatever-sized parts one wanted for halves or thirds? The whole formalism with its handy algorithms would break down. To understand the consequences of *not* holding to the equal parts rule is to understand more than the rule itself, grasping something of its functional necessity.

Any discipline, including the sciences, mathematics, art, literature, or history, has an epistemic layer concerned with canons of justification. In the scientific community, for example, a strict standard of coherence in the formulation of a theory constitutes one of the primary "rules of the game" by which scientists judge validity. Small inconsistencies and mismatches with data call for careful scrutiny and may topple theories if they cannot be accounted for otherwise. However, students, not having assimilated the culture of science, often seem unimpressed by the "minor" anomalies that some instruction seeks to impress them with, in order to encourage them to revise their naive theories.

While a weak epistemic frame may undermine content learning, a strong one may abet it. Students who have developed a sense of the demand for coherence in science are more likely to take seriously the "minor" anomalies. Or, for an example from mathematics, students often exhibit "malrules"--mistaken computations such as distributed the radical sign over a sum (Resnick, 1987). Students are often encouraged to check transformations they are uncertain about with arithmetic, but tend to resist this. Novices may judge such "rules of the game" as checking with arithmetic to be rote formalism. However, an epistemological understanding of the motive can help. For example, since the grounding of rules of algebra lies in the rules of arithmetic, checking algebra against arithmetic is exactly the right step to take, a turn to the epistemological foundations of algebra. Students who appreciate this in a common sense way are perhaps more likely to make the move.

One can go much further in showing how understanding something is inherently a multidimensional pursuit. Understanding even something as simple as the equal parts rule for fractions involves a myriad of relationships with other ideas at many levels. Whatever one's particular analysis, at the least we should say that understanding something involves not one or two or three mental models for it, but a network of mental models at various levels of abstraction and with various other affiliations, that impinge on the concept in question.

It is worth noting also that navigation through this network of models is not necessarily very expert-like. It is only expert-like when one traverses very familiar regions of the network that have been overlearned and "compiled" into efficient recognitional responses. But much of the interesting work of understanding occurs on the fringes of the very familiar regions, in a more halting and belabored way, more tentative and conjectureful, but often enormously rewarding.

Problem Solving

Problem Solving Heuristics

Problem solving is a key activity in science and mathematics. Accordingly, we do well to look at it as an indicator of achieved ability. The characteristics of expertise and understanding already discussed, of course, contribute to effective problem solving. But there is a side of problem solving not addressed by the themes of having a large repertoire of schematized concepts and a deeper understanding of the epistemic roots of a discipline: the art of problem solving, as it involves heuristics of problem solving.

The notion of heuristics of problem solving has been particularly well developed in the context of mathematics. The classic source here is the work of the mathematician Gyorgy Polya, who, in a two volume treatise and a popularization called *How to Solve It*, presented a forceful counterthrust to the notion that mathematical proofs and derivations arise by mental processes that mirror their methodical logical structure (Polya, 1954, 1957).

Polya celebrated instead the importance of heuristic practices in constructing proofs and derivations. He urged that the creative work of mathematics depends crucially on a sizable repertoire of pragmatic moves that, while not guaranteeing resolution in any algorithmic sense, commonly open the way to fully formal solutions. Among the heuristic moves Polya discussed were such tactics as examining problems through diagrams, considering special cases, breaking problems into subproblems, solving simpler problems resembling the problem at hand first, generalizing problems in hopes that the more general version would actually be more accessible, and more.

Polya thought that heuristics were the key to imparting mathematical problem solving skills, and other mathematicians and educators seized upon this idea with enthusiasm. Ample evidence accumulated that mathematicians indeed depended considerably on the use of heuristics. However, significant barriers stood in the way of students quickly learning heuristics and putting them to work. One difficulty, for example, was that students commonly would simply forget to try to apply heuristics while in the midst of problems. Another was that students often would not quite know how to go about instantiating a heuristic to a particular case. It is one thing to recognize that breaking a problem into subproblems is likely to pay off, but quite another to have sufficient understanding of a domain to be able to isolate subproblems (Schoenfeld, 1978, 1979).

Heuristics Plus Problem Management

Eventually someone managed to put together the several strands needed to bring heuristics into their own. Alan Schoenfeld, a mathematician intensely interested in education and cognitive science, managed to demonstrate impressive gains in college students' problem solving through interventions providing them with Polya-like instruction (Schoenfeld, 1982; Schoenfeld & Herrmann, 1982). Schoenfeld was also able to demonstrate transfer effects to problems somewhat different from those in the instruction. A further finding was that students' perceptions of problems shifted to a more expert-like pattern, in accordance with the "quick orientation" findings regarding expertise discussed earlier.

Schoenfeld's success depended on significant innovations in the handling of Polya-like heuristics. For one, Schoenfeld presented the heuristics carefully fleshed out with real mathematical contexts, and formulated with details that made clear how they would play out mathematically. For example, not just "look at special cases" but what sorts of special cases might profitably be examined was emphasized. For another, Schoenfeld offered not only heuristics but an overarching problem management strategy that helped students to organize their attacks on problems. This strategy pressed students to orient to a problem thoroughly at the outset, check carefully at the end, monitor progress periodically, and shift directions if an approach was not paying off, and pursue other broad tactics designed to avoid a number of typical student shortfalls.

In recent writings, Schoenfeld has emphasized that good handling of matters mathematical calls for more than just heuristic repertoire, problem management, and, of course, knowledge of the domain (Schoenfeld, 1985). There are general attitudes and background beliefs regarding the mathematical enterprise that can have a substantial influence on students' practices. For example, many students harbor the belief that "if you can't solve it in five minutes, you can't solve it at all." Such a belief, of course, undermines a proactive posture toward mathematical problems and practically ensures little systematic learning of problem solving methods.

Thus, skillful problem solving in mathematics and the sciences depends on a repertoire of heuristics, good problem solving management practices, and also conducive understandings of and attitudes toward the fields of mathematics and science. Moreover, such heuristics, problem management practices, and attitudes can be inculcated to some extent.

Beyond Problem Solving: Problem Finding

Thinking of good problem solving as the heart of good performance in science and mathematics is natural. However, such a view leaves important parts of inquiry untouched. Professional practice plainly calls for considerable attention to "problem finding," the ferreting out and formulating of problems worth solving. One is reminded again of Thomas Kuhn's notion of normal science. Problem solving is entirely too much "business as usual." In fact, it is only a limited part of even "normal science," since when scientists pursue work within a paradigm a significant part of that work consists in finding new puzzles to address and sorting them out within the boundaries of the paradigm. Biographical work on creative scientists and mathematicians offers plentiful evidence of their attention to problem finding and their flair for sorting out more from less worthwhile problems.

In contrast with problem solving, the cognitive constituents of effective problem finding have not been extensively studied. Evidence not from mathematics or the sciences, but from the creative performance of student artists, argues that one important factor is simply the allocation of substantial attention to searching out and formulating problems (Getzels & Csikszentmihalyi, 1976). Psychological models aside, mathematics educators have devised provocative approaches to engaging students in problem finding activities, which play hardly any role in the normal curriculum. Brown and Walter (1983) offer a systematic approach to problem finding that depends on such powerful questions as "what if not," as ways of transforming given propositions into fresh and unexplored ones. Schwartz and Yerushalmy (1987) offer an approach to instruction in plane geometry that casts students in the role of discoverer of theorems, organized around a piece of software called *The Geometric Supposer* that makes geometric constructions easy and so allows students to explore possibilities fluently.

Part II: Precursor Abilities

We have seen that achieved ability in a scientific or mathematical domain is quite complex. In a general philosophical sense, this should not surprise us. But in a more specific sense, we may be a little startled by the many sides of achieved ability. As reviewed above:

- The phenomenon of expertise testifies to the importance of a large knowledge base of domain specific schemata, reflexively accessed, underlying achieved ability.
- At the same time, the use of more general principles and analogies is implicated in *flexible* expertise.
- Mental models providing dynamic envisionments, default values, and related kinds of information figure importantly in understanding key concepts in a domain.
- At the same time, "one mental model per concept" will not do. Achieved ability depends on a multilayered network of mental models, including models addressing the epistemology of a domain and other matters more abstract than the nature of particular content concepts.
- Problem-solving ability depends on a repertoire of heuristics and problem management techniques, as well as on domain specific expertise and understanding.
- Beyond problem solving, problem *finding* ability has to be considered a crucial part of achieved ability in a domain.

All this sets the stage for examining the other side of the abilities question: precursor abilities. Okay, Ted knew that the good use of fractions called for division into equal parts; that particular achieved ability might involve some sort of mental model, for instance. But what sorts of abilities predating Ted's savvy about halves or, indeed, his learning about fractions at all, put Ted in a position to get the matter of equal parts straight while many other children do not? Indeed, can such an outcome be explained to any significant degree by precursor abilities, or does one need to turn to other factors entirely, such as motivation or good teaching or conducive environment?

Of course, such questions asked of an isolated achievement such as Ted's response afford little hope of plucking a good answer out of the many possible causes. But suppose we speak of achieved ability over a broader front--being good at mathematics or physics in a general way. Then, what abilities if any can be seen as precursors to such achieved abilities, offering some prediction and explanation of why those achievements came about. Such a precursor analysis evidently has great importance for our understanding of scientific and mathematical talent.

Before turning to particular proposals for precursor abilities, it is useful to envision what an ideal account of such abilities might be like. As noted, forecast is one aim. As an ideal criterion, one would particularly like forecasts that do not involve already demonstrated achievement in the domain in question, because detecting potential in a domain in advance of actual work in the domain is desirable.

Explanation is another function of precursor abilities. One would like such phenomena as demonstrated talent in a domain, insightful understanding, problem solving prowess, and so on, explained by reference to precursor abilities out of which these achieved abilities develop. Again, a good precursor explanation would not involve precursor abilities that already constituted achievement in the domain in question. After all, to explain further achievement in terms of achievement so far is to do little more than take what we've already discussed--achieved ability--and say that *it* explains more of the same. It's like explaining a mature oaktree by pointing to an oak sapling and saying, "It keeps growing in about the same shape!"

For both predictive and explanatory reasons, then, one would like to find precursor abilities with a distinct "remove" from the nature of the achieved abilities. This, as will be seen, is not an easy challenge to meet. We turn now to an appraisal of several candidate precursor abilities.

General Intelligence

Perhaps the most obvious candidate for a precursor ability is the well-known *g* of general intelligence. The aim of *g* is to serve as an index of a broad-band mental ability that manifests itself in virtually all performance contexts. Indeed, we do well to recall that this is the very basis of the construction of *g*. If one gives individuals a variety of intellectually challenging tasks drawing on various domains--language, mathematics, pictorial tasks, and so on--one invariably finds considerable intercorrelation among performances on the instruments: Those who do well or poorly on one tend to do well or poorly on the others. The common trend can be extracted statistically, and yields the *g* measure, a numerical effort to capture whatever it is that enabled the person to perform at a certain level across the various tasks.

While *g* in itself is a mere measure, not a model of anything, models of the mechanism that *g* reflects can be constructed. For example, Arthur Jensen argues that *g* is an index reflecting the fundamental efficiency of the neurological system in processing information of any sort (Jensen, 1984). Jensen buttresses this argument with a series of experiments that demonstrate correlations between *g* as conventionally measured and performance on what is called a "choice reaction time" task. This task requires subjects to make a rapid choice between varying numbers of buttons in different conditions: two, four, or eight buttons. Taking the log base 2 of the choices yields a measure of information that proves a linear predictor of certain aspects of subjects' reaction times in responding, one reason one might agree that a fundamental characteristic of information processing is implicated.

Then does *g* offer the ideal precursor ability we want? Consider first the predictive side of the question. In some ways, *g* shows definite promise. Virtually all studies of high achievers in intellectually demanding domains have shown these talented individuals to have relatively high *g* (Grinder, 1985; Sternberg & Davidson, 1985). Accordingly, *g* affords significant predictive value in forecasting high achievement.

On the other hand, such predictions are starkly limited by a further finding: Having a very high *g* in no way guarantees truly exceptional achievement (Grinder, 1985; Sternberg & Davidson, 1985; Wallach, 1985). Specifically, within a profession, correlations between *g* and professional productivity tend close to zero. For example, professional physicists with exceptionally high *g*'s are no more productive or creative than those with lower *g*'s. One way this result is sometimes stated is to say that *g* functions like a gatekeeper to certain professions: You simply do not become a professional physicist unless you have a good *g*. But among professionals, *g* has no further predictive power. To put it another way, a fairly high *g* serves more as a necessary than as a sufficient condition for high achieved ability: One does not find such achievement without a high *g*, but a high *g* comes nowhere near guaranteeing special achievement.

Yet another qualification on the predictiveness of *g* is that *g* corrected for age, that is, IQ, is not at all an invariant trait (Humphreys, 1985). An individual's IQ can drift up or down considerably as the individual matures. Specifically, the correlation between *g* at a given point in time and *change* in *g* over some period thereafter, say a year, is about zero. That is, as *g* increases with age, a person is about equally likely to gain or lose ground relative to peers. In IQ terms, IQ is equally likely to drift up or down.

Thus, one simply cannot view a person with a normal or below normal IQ as somehow trapped by a ceiling level of intellectual capacity. That person's IQ may well rise. Likewise, one cannot view a person with high IQ as somehow supported in intellectual performance by some floor capacity. That person's IQ may well drop.

If *g* is only a so-so predictor, what about *g* as an explainer of later achieved ability? Again, *g* or rather the mechanisms underlying *g* certainly offer something toward an explanation. For example, adopting Jensen's notion of effective information processing, we certainly find in that notion a precursor ability well removed from the particular achieved ability of a mathematician proving theorems in differential geometry or a physicist developing a theory of superstrings (Jensen, 1984).

At the same time, though, we might feel uneasy that *g* does not offer anything toward a *selective* explanation of special achievement. Certainly it seems that different individuals often display particular talents for different domains. One gifted person may incline to mathematics, another to painting,another to music. However, *g*, domain-neutral as it is, does nothing as a precursor to reflect such early leanings. It thus explains less than we would like to explain.

Why might it be that *g* is neither as predictive nor as explanatory as one would like? This is a surprisingly easy question to answer. First of all, numerous studies of talent have demonstrated that high motivation plays a crucial role in high achievement. One simply does not find prodigious development in youngsters who have not committed themselves to extensive work in a domain (Bloom, 1985; Feldman, 1986). This result makes sense in terms of the research on expertise cited earlier, with its emphasis on a large knowledge base of schemata and on the time needed to acquire such a repertoire. It also reminds us that achieved ability will vary strongly with time-on-task, and that, in turn, will vary as strongly with motivation as with a precursor ability such as *g*. Opportunity to learn, including access to special tutors, is of course another factor that has been shown to be important in developing talent and hence another factor introducing variance.

These considerations aside, a further element that may limit the relevance of *g* is the possibility that intelligence is much more multifold than monolithic. While *g* aims to compress variations in ability into a single measure and a single distributed property of the nervous system, say Jensen's information processing ability, numerous investigators have suggested that intellectual competence rests in several somewhat independent factors. The following two sections address expanded notions of intellectual competence in this spirit.

Multiple Intelligences

An approach better suited to accounting for special talents might be Howard Gardner's theory of multiple intelligences (Gardner, 1983). In his theory, Gardner criticizes the view of intelligence as a general capacity, arguing instead for a broader and more universal set of intelligences than those typically considered. In stark contrast to theories propounding the existence of a general intelligence, Gardner maintains that individuals have a number of domains of potential competence which they may develop assuming the appropriate stimulating factors are accessible.

Defining intelligence as the ability to solve problems or fashion products that are deemed of value in some cultural context, Gardner proposes a set of seven competencies or intelligences. Underscoring the point that no one list of intelligences covers the full range of cognitive capabilities, Gardner focuses his discussion on the following: linguistic intelligence, musical intelligence, logical-mathematical intelligence, spatial intelligence, bodily-kinesthetic intelligence, and two aspects of personal intelligence, intrapersonal and interpersonal. Gardner stresses that intelligences normally considered outside the traditional realm of the study of cognition, for instance, the personal or musical intelligences, in a broad sense, hold equal status to those typically held at a premium in our schooling and testing practices, namely logical-mathematical and linguistic abilities.

These seven competencies, Gardner argues, act relatively independently of one another, so that, for example, one's linguistic ability cannot be inferred from one's competence in music or logical-mathematical intelligence. While maintaining the importance of isolating competencies in discussing the structure of human cognition, Gardner notes that any adult recognized by society as particularly gifted in a certain area, say in musical intelligence, undoubtedly possesses a blend of well-developed intelligences. Thus, in addition to heightened musical talents, the musician may possess a highly developed interpersonal competence that allows for communication with an audience, as well as some bodily-kinesthetic skills that enable him or her to achieve subtle effects on a particular instrument.

Gardner argues that the current system of intelligence testing skews results in the direction of those who possess linguistic and logical intelligences. He maintains that even tests that *seem* to measure spatial or other abilities are constructed so that they primarily call upon linguistic and logical facility; accordingly, individuals who do well in these areas are more likely to perform well even in tests of spatial or musical abilities. Conversely, individuals with strengths in other areas, but not highly developed in logical or verbal skills, will not fare well on such tests. Gardner advocates the construction of "intelligence-fair" instruments that would more adequately assess the intelligences in question. He suggests, for example, that an assessment of spatial ability might involve navigation about an unfamiliar environment as opposed to the typical series of multiple choice geometric rotations.

How well does the theory of multiple intelligences speak to our search for precursor abilities? In contrast to *g*, the theory offers an explanation of special abilities in particular domains. And, as an explanatory device, the theory of multiple intelligences does indeed offer an explanation of talent removed from its playing out in a discipline. Indeed, Gardner views the seven intelligences to have to a considerable degree neurological bases, corresponding to different "organic computers" within the larger system of the brain. Gifted individuals may well be gifted in virtue of better "original equipment," although Gardner also emphasizes the impressive power of artful instruction, pointing to Suzuki violin instruction as an example.

Without engaging the technical details of Gardner's and rival theories, a reservation one might have about its explanatory power is simply that the theory of multiple intelligences cannot be viewed as established. It, along with virtually every other theory of intelligence propounded in this vexed area of the psychology of mental competence, is quite controversial. Indeed, there is a history of efforts to break *g* down into well-defended subcomponents, including,for example, J. P. Guilford's ***structure of intellect*** theory, several components of which anticipate Gardner's multiple intelligences model. These efforts have been criticized for failing to make a technically good case for multiple components of intelligence (Grinder, 1985; Humphreys, 1985).

What about the quest for a *predictive* account of precursor abilities? In this regard, a problem with the theory of multiple intelligences as it stands today is the lack of instrumentation available to measure the intelligences. While Gardner himself recognizes this dilemma, advocates the development of such measures, and is engaged in such work, the gap remains and for the present, at least, limits the usefulness of the theory to deliberations of an explanatory rather than a predictive nature.

Moreover, Gardner's conception of appropriate means to develop measures of the intelligences emphasizes engaging students in activities characteristic of the domain in question, often quite rich activities. Such measures sacrifice something of the "remove" called for earlier, coming close to gauging achieved ability. The sacrifice may be appropriate. One can understand the sensibleness of Gardner's approach: What better probe of an intelligence than rich tasks from the domain in question? Still, this pushes matters toward the "sapling" model, that gauges the height of the mature tree by the height of the young tree.

Finally, such measures, if developed, might still prove problematic in much the same way that *g* does. To be sure, they would honor a greater range of human capacities. Nonetheless, as previously noted, there were good reasons why *g* appeared to function more as a necessary than a sufficient condition for high achieved ability. The same sorts of reasons seem likely to apply to measures of multiple intelligences. As discussed earlier, other intervening factors, such as motivation and opportunity to learn, affect achievement and thus would interfere with the predictive ability of Gardner's intelligences.

Gardner's own theory compounds the sources of variance, because of his reasonable insistence that a particularly able individual's performance is likely to involve the significant exercise of a portfolio of intelligences. If a fine musician's achievement involves a number of competencies, how is one to predict? Apparently not on the basis of musical intelligence alone, which would seem to be a necessary condition only. But what others might be called for? Different ones in different cases, perhaps.

The Triarchic Theory of Intelligence

Yet another contemporary view is Robert Sternberg's *triarchic theory of intelligence* (Sternberg, 1985). In the present context, we will focus on one aspect of this complex theory, its major tripartite division. Sternberg defines three subtheories--hence "triarchic"--termed the *contextual, experiential,* and *componential* subtheories. Sternberg avers that these represent contrasting aspects of intelligence and that taken together they encompass far more of what intelligence ought to mean than the traditional *g*. A person may be more or less high in any one of the three aspects somewhat independently of one another.

The contextual side of intelligence concerns a person's adaptation to environment, including social milieu. Sternberg notes that some people may be exceptionally well adapted to intellectual environments--universities and research laboratories, for example--without necessarily being strikingly creative or extremely bright in an academic sense. They may be good organizers, good promoters of themselves and others, and build quite a reputation by knowing how to move well in the world they occupy. As Sternberg notes, in our more critical moments we may call them "operators."

The experiential side of intelligence concerns a person's ability to adapt to novel tasks and situational demands, both by insight into new situations and by efficient automatization of responses to deal with recurrent situations. In this aspect of intelligence one finds giftedness in the "great person" sense --the Einsteins, Beethovens, and others who remake fields in fundamental ways. Such individuals may be far from "operators," of course.

The componential side of intelligence concerns a person's ability to process information effectively via a number of components defined by Sternberg. Prominent among these are "metacomponents," several very general components that exercise a control function over the organism. Examples of metacomponents include "Decision as to just what the problem is that needs to be solved" (Sternberg, 1985, p. 99) and "selection of one or more representations or organizations for information" (Sternberg, 1985, p. 100). Conventional academic performance and *g* are most closely related to strong components, particularly strong metacomponents, according to Sternberg. Of course, many individuals prove strong academically without exhibiting either the flair for insight of the experiential side of intelligence or the flair for maneuvering of the contextual side of intelligence.

This does not mean, however, that these components play no role in the experiential and contextual sides of intelligence. Actually, the componential side of intelligence is less a third side than an undergirding relevant to all handling of information.

To understand Sternberg's perspective, recognizing that two of the subtheories in the triarchic theory have familiar ancestor is helpful. Roughly speaking, the componential theory is meant to be a sharper articulation of the component processes involved in conventional *g* and what might be called "academic intelligence." The experiential side is in large part an effort to map insight and creativity. There is a long and, at least, somewhat successful history of efforts to separate academic intelligence from creativity and a number of different approaches to doing so, to which the triarchic theory may be added (cf. Perkins, in press). Academic intelligence and creativity are, of course, the two sides of intelligence most directly germane to academic giftedness as normally conceived. Less precedented but also relevant to academic giftedness is Sternberg's introduction of the contextual side of intelligence.

How does Sternberg's triarchic theory fair as an account of precursor ability? In principle, the triarchic theory offers good "remove" from particular achieved ability in science and mathematics. It is not formulated in domain-specific terms, and the sorts of measures discussed by Sternberg do not require achievement in depth in particular disciplines. Accordingly, the triarchic theory offers the potential for the sort of distanced prediction and explanation that an ideal precursor account demands.

What can be said about its predictive function specifically? Here we encounter a problem somewhat analogous to that examined in the discussion of Gardner's theory of multiple intelligence. Although Sternberg does propose some measures, by and large, there is no substantial validation of them against individuals of genuine real-world achievement. Nor is there any reason to think that Sternberg's measures overall would be any *more* predictive of academic and creative performance than prior efforts to forecast such abilities.

In sum, the best assessment at present of what Sternberg's account might offer predictively is simply what tests of academic intelligence and creativity have offered in general. What tests of academic intelligence--*g*--put forth has already been discussed. Regarding creativity testing, the basic point to make in this context is that such tests have proved weakly predictive at best (cf. Wallach, 1976a,b, 1985). The best measures have been shown to be not cognitive instruments but personality profiles, and even better than that is track record in a domain (Mansfield & Busse, 1981). In other words, the available instrumentation in precursor abilities comes nowhere near the predictiveness of achieved ability during engagement with a discipline.

With this said for *prediction*, how does the triarchic theory fare as *explanation* for talent in science and mathematics? Unlike Gardner's theory of multiple intelligences, the triarchic theory in its basic structure does not offer any account of field-specific leanings. In this respect, therefore, we may feel disappointed if, indeed, we believe that field-specific leanings exist before actual engagement with a field.

In its componential subtheory, the triarchic theory presents a much better articulated conception of how academic intelligence works than conventional accounts, with an emphasis, in our view appropriate, on metacomponents that play a crucial organizing role in the deployment of mental resources. We note that Sternberg's particular choice of metacomponents lacks strong support and that one might propose many other sets of metacomponents of equal plausibility. Nonetheless, the triarchic theory offers one such organization and viewing intelligent functioning at that "metalevel" provides explanatory power lacking in more monolithic and single level concepts of academic intelligence.

The triarchic theory of intelligence also offers a theory of insightful thinking that highlights the three operations *selective encoding, selecting combination,* and *selective comparison*. These provide a framework for discussing episodes of insight in a systematic manner. However, as Perkins (in press) argues, the same framework functions just as well for discussing quite mundane contexts of information processing; a case is lacking that these operations are *distinctively* involved in insightful thinking in a noncircular way.

In sum, the triarchic theory seems to be particularly useful in explaining academic intelligence, less useful in accounting for insight and creativity, and distinctive talents.

Developmental Level

Another very different approach to seeking precursor abilities is to turn to concepts from the field of human development. Piagetian stages provide obvious candidates for precursor abilities. For example, certain concepts important in science and mathematics simply are not accessible until an individual has attained formal operations. Moreover, with formal operations available, the individual should have no great difficulty attaining these concepts.

As with Gardner's theory of multiple intelligences and Sternberg's triarchic theory, Piaget's notions of concrete and formal operations satisfy the requirement of "remove" for precursor abilities. Concrete and formal operations are conceived to be quite general cognitive structures not strongly affiliated with any particular disciplinary expertise. From this standpoint, concrete and formal operations make attractive precursor abilities.

The difficulty is that cognitive developmental research over the last two decades has pretty much discredited these Piagetian notions as originally conceived (Carey, 1985a, b; Case, 1985; Brainerd, 1983; Fischer, 1980; Fischer, Hand, & Russell, 1984). Extensive evidence has accumulated against the idea that there are sweeping stage transitions in which numerous concepts across many domains suddenly become quite accessible to the learner. The current view is overwhelmingly that there are individual developmental trajectories in different domains, strongly influenced by the structure of knowledge in the domains. Even Piaget late in his life acknowledged phenomena of this sort (Piaget, 1972). Thus, for example, a youngster who had for one reason or another received extensive exposure to and involvement with mathematical thinking might display patterns of mathematical reasoning of a fully formal character, while the same youngster might evince much less sophisticated thinking in other contexts.

This shift away from the idea of overarching developmental stages is, of course, tied intimately to the research on expertise reviewed in the first part of this document. With the recognition of the importance of a rich knowledge base in accounting for expert performance came a correlative recognition that early development of school competencies might also reflect particular knowledge more than anything else. Accordingly, some developmentalists now argue that cognitive development is *nothing but* the acquisition of various kinds of knowledge, much of it but not all of it domain specific (Carey, 1985a, b). The case can be made that developmental psychology would best inform education through cleaving closer to subject matter learning while preserving important developmental themes (Strauss, 1986, 1987).

Recent years have seen a resurgence of models of development that rescue various parts of Piaget's conception. The developmental theories of Robbie Case and Kurt Fischer are examples of these perspectives (Case, 1985; Fischer, 1980;

Fischer, Hand, & Russell, 1984). Both offer structural concepts of mental organization that illuminate the process of coming to understand concepts and processes within a domain. By and large, however, these neo-Piagetian models do not offer precursor abilities with "remove" from achieved abilities, exactly because they highlight the importance of domain-specific learning. Rather, they basically enrich our conception of what achieved abilities are like and how achieved abilities of a certain complexity and degree of integration can lead to other achieved abilities of greater complexity and integration.

The Cognitive Roots of Ability

With these ideas examined, it is appropriate to stand back and see where we are. In quest of the cognitive roots of scientific and mathematical ability, we have sought to characterize *achieved ability*--what sorts of cognitive structures and processes mediate competence in a domain? We also have sought to characterize *precursor ability*--what cognitive structures and processes "removed" from the domain of interest, here science or mathematics, predict and explain achieved ability in the domain? Let us consider what we have found out about each of these questions, beginning with the latter.

Precursor Abilities

Our analysis offers a number of "softly necessary conditions" with some "remove" from achieved ability and some explanatory power. Among these precursor abilities we find the classic notion of general intelligence, Gardner's theory of multiple intelligences, and Sternberg's triarchic theory of intelligence.

Ideally, however, one would hope for a much stronger account of precursor abilities. The "softly necessary" character of the aspects of intelligence identified makes them only predictive--and indeed explanatory--in a very partial way. Of course, other than in the case of *g*, our only evidence for the "softly necessary" character of these aspects of intelligence is our own reasoned judgment, because of another unfortunate circumstance, the lack of actual measures representing adequately either the theory of multiple intelligences or the triarchic theory. It must be added that significant controversy surrounds all these precursor theories, including *g* itself. Finally, while insight and inventiveness would naturally be of special interest in considering education for the talented, the experiential component of Sternberg's theory may not even provide "softly necessary" conditions. At least somewhat analogous efforts to measure inventiveness in cognitive ways have a very checkered history, while personality factors and, especially, track record have proved much better predictors.

It seems clear that, if one wants to move toward sufficient conditions, nothing comes close to beating the "sapling test"--actual achieved ability in the domain at a certain point in time. We can understand why in light of the complexity of achieved ability: So many dimensions and aspects are involved that achieved ability is hard to predict in a sufficient condition sense by anything else other than prior achieved ability in the same domain. One is even tempted to question whether a strong theory of precursor ability is possible. There may be too much room for variation in individual histories and the factors important in those histories.

Achieved Abilities

If contemporary psychology offers a rather limited account of precursor ability, it serves up quite a rich account of achieved ability. Recall that the survey in Part I of this article identified at least the following elements:

- "Compiled" domain-specific repertoires of schemata.
- Flexible access to more general schemata.
- Mental models of many sorts serving understanding.
- Multilayered networks of mental models.
- Heuristic and problem management tactics.
- Problem finding abilities.

Moreover, the perspectives reviewed in Part II, whatever their contribution to an account of precursor abilities, expand our understanding of achieved ability further by introducing yet more elements to take into account. Although these elements overlap somewhat with those introduced in Part I, they are very much worth considering. Here is a partial list:

- Achieved competence in the several intelligences.
- Achieved competence in metacognitive components.
- Achieved competence in insight-related processes.
- Achieved domain-specific developmental integrations.

Implications for Educational Practice and Research

Selection of talent. The distillation of the perspectives reviewed here suggests that selection of talent should focus on early achieved ability, the "sapling" approach. Simply put, no strongly predictive measures of precursor ability are available. A number of measures could be used for screening as "softly necessary conditions," but they should not be seen as ensuring high achieved ability in the domain in question. Moreover, the "softly necessary" should be remembered: That any such measures, as with IQ, will be subject to upward and downward drift relative to peers is likely. Finally, it is important to remember that selection of an extreme group is subject to effects of regression to the mean (Humphreys, 1985); the group probably will never be quite as special as when it was selected!

In terms of research, the theories reviewed both in Part I and Part II suggest that the bases for examining achieved ability for predictive purposes might be broadened considerably. For example, one might test seemingly talented individuals not only for conventional problem solving but for problem finding. One might employ measures of insightful problem solving or of personality trends. One might check for a precocious understanding of the epistemic side of the discipline in question. One might gauge ability in an intelligence central to the discipline in question, plus correlative intelligences thought likely to make particularly important contributions.

Whether any of these probes would, in fact, increase the predictiveness of the "sapling" approach is, of course, an empirical question. However, it is easy to see how they might: by broadening the measurement process to include a number of very important factors that typically remain untapped by conventional measures.

Instructional practice. The multifaceted nature of achieved ability and the subjectness of precursor abilities to drift also have definite implications for instructional practice. The drift effect implies that, certainly, one should not take for granted continued "automatic" development of the talented or the "automatic" slow development of the less talented. A drifting system invites boosting in desirable directions. Too often, teachers and parents treat either slowness or giftedness at a certain point in a child's development as a durable trait sure to play out to a clear destiny. Such an attitude is likely to lead to undeserving both slow and gifted students.

As to the multifaceted nature of achieved ability, each facet recognized shows conventional educational practice to be all the more reductive. Most of the facets discussed--for instance problem solving heuristic, the epistemic frame, mental models--are simply not substantively addressed at all in conventional education. Instruction truly seeking to enhance achieved ability needs much greater scope. The aspects of achieved ability identified provide a useful guide to what *sorts* of scope might be helpful. One might look toward "wide spectrum education" (WISE for short!) that attends to education in the subject matters with much more respect for the many aspects of achieved ability.

"Wide spectrum education," through addressing the many aspects of achieved ability better, offers the hope of capturing individual talent better. Particular students might well prove more or less responsive to different facets of achieved ability within a discipline. Some learners might need or especially value concrete mental models of basic concepts; others, an epistemic understanding of the domain so that it seems better justified; others, problem solving management techniques, and so on. Each facet also helps the whole to make more sense, and so many more students who now find education exciting and effective might discover entry ways into achieved ability through a wide spectrum approach.

While a broad prescription for educational reform, these ideas also write their own research agenda. An instructional process as rich as envisioned here plainly runs the risk of utter impracticality. Design questions arise: What can be done for expanded range with reasonable effort? Impact questions arise: When such plans are followed, what are their effects? Innovations such as the notion of "metacourses" discussed earlier designed to bring wider spectrum education to conventional educational settings, invite systematic research (Perkins, Schwartz, & Simmons, in press; Schwartz, Niguidula, & Perkins, 1988).

All in all, this two-part effort to examine the cognitive roots of mathematical and scientific ability has yielded a worthwhile harvest, if not a cornucopia. A good deal can be said about *achieved ability*, including the notion that early achieved ability, given learning opportunities, seems like the best predictor of later achieved ability--the "sapling test" appears much superior, its lack of remove notwithstanding. Some broad implications for educational practice and research also follow.

As to the second part, sifting from contemporary cognitive psychology a strong theory of *precursor abilities* has proved move difficult. Indeed, the available efforts in that direction may contribute more in rounding out our notions of achieved ability than in building the ideal precursor theory. Well, as the saying goes, half a loaf is better than none. And, if we are right in our speculation that an ideal theory of precursor abilities may simply not be possible, and since Ted is not sitting across the table, we are tempted to say that the half we have is the larger half.

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Discussant Reaction:
Alternative Representations: A Key To Academic Talent?

Ruth S. Day

It is a tall order to understand the cognitive roots of scientific and mathematical ability. Nevertheless Perkins and Simmons (1988) have provided a useful overview of this complex problem. Central to their discussion is the contrast between two general classes of abilities, those which have already been achieved and those which are precursors to such achievement.

Achieved Abilities

In discussing achieved abilities, Perkins and Simmons reviewed three research traditions and implied how each reveals important aspects of cognitive talent. Thus, according to their view: 1) Research on expertise recognizes domain specific schemes, and talented individuals should have many such schemes and have flexible access to them. 2) Research on understanding emphasizes the role of mental models, and talented individuals should have many such models arranged in multilayered networks. 3) Problem solving research emphasizes the role of heuristic, management, and problem finding, and talented individuals should have more and better heuristic, manage the problem solving process more efficiently, and be better able to find problems as well as solve them.

Precursor Abilities

In discussing precursor abilities, Perkins and Simmons highlight four research traditions (general intelligence, multiple intelligences, triarchic theory, and developmental level) and evaluate each in terms of its ability to explain and predict talent. Unfortunately, they are not very sanguine about the accomplishments of these approaches. Given sufficient time, I would suggest another type of precursor ability, overall cognitive pattern (Day, 1977), which may predispose individuals to have different types of cognitive talents. I would also expand the achieved-precursor paradigm to study how these two types of abilities might interact with each other. Such discussion might suggest new approaches for theory, research, and educational practice. However, since this presentation must be brief, I will only discuss the concepts of alternative representations and problem finding as mentioned above.

General Approach

In the research reported below, we identified several academic problems and then translated them into carefully controlled laboratory experiments. Unless indicated otherwise, subjects were undergraduates at Duke University. Since Duke students have average combined SAT scores above 1300, they are quite academically able; however, not all would be classified as academically "talented." In all experiments, subjects were assigned randomly to the various treatment conditions. Implications of this work for understanding and fostering talent are presented at the end of this paper, along with a fairly unorthodox view of talent.

The Alternative Representations Approach

Two simple notions introduce the alternative representations approach (Day, 1988). First, all ideas can be represented in many different ways--such as sentences, lists, outlines, tree diagrams, matrices, graphs, and pictures. This is true no matter whether the content involves academic or everyday information, is simple or complex, brief or extensive in length. Second, the way we represent a given idea has clear cognitive consequences. That is, representations affect cognitive processes such as perception, memory, concept formation, comprehension, and problem solving. To illustrate these notions, this discussion includes examples from specific science domains as well as some which cut across domains (text editing, data analysis). The discussion concludes with implications for understanding the nature of talent and form modifying instructional practice.

Chemistry Molecules

Many students have great difficulty learning organic chemistry. For example, the Duke University *Chronicle* (March 27, 1984) titled an article describing this problem as, "Pre-Meds Face the Wrath of Orgo, the Killer Course." There are many reasons why organic chemistry is so difficult, including the sheer amount and complexity of the information involved. We have been studying another possibility, that the notation systems chemists use to represent three-dimensional molecules in two-dimensional form (in textbooks, on blackboards) may be part of the problem (Day, 1984). A quick look through any organic chemistry textbook reveals a wide variety of diagrams such as those shown in Figure 1. To what extent does each type of representation help or hinder understanding the molecules?

In our experiments, subjects were undergraduates who had taken one high school or college chemistry course; thus they were like those who typically enroll in organic chemistry. They handled a tinker-toy model of a new molecule we devised and learned to represent it in various standard notation systems. Then they saw two such displays and had to determine whether they showed the same or different molecules. Their performance depended on what notational system we used; one system was easy to use and led to superior performance while another was difficult and led to inferior performance. The properties of these notations are described elsewhere (Day, 1984; in preparation); for simplicity here, they are called the "easy" and "difficult" notations.

Clearly, we can make it easier or harder for students to understand chemistry molecules, simply by using alternative representations of the same information. A more provocative way to say this is that we can make students appear to have more or less "chemistry talent," simply by using specific representations. Curiously, the difficult notation we used is introduced early in organic chemistry courses and used heavily throughout the course, while the easy one is introduced much later; by that point, many students have fallen behind, become confused, or even dropped the course.

Hardware Design

Designing hardware for a computer involves a considerable amount of knowledge and skill, including physics, electronics, computing, design, and problem solving. Yet a given project will consist of many quite small units, or "cells." Current research in our lab represents such cells in alternative ways, emphasizing their electrical or logical properties. Subjects are graduate students who have had at least one course in VLSI (very large-scale integration) but little if any experience beyond such coursework; thus they are VLSI novices--somewhat knowledgeable but inexperienced. Subjects inspect cells one at a time and try to determine their general function. Although they are highly accurate in this task, alternative cell representations affect the speed with which they can respond--and thereby understand the function of the cells. It is important to understand the function of many cells at once during normal design tasks; hence, alternative cell representations may well affect engineers' ability to develop hardware systems in both a quick and efficient manner.

Text Editing

Computer text editors enable users to modify text quickly and easily--to delete, add, modify, and rearrange units as small as single letters and as large as entire sections of manuscripts. Despite the many advantages of such systems, learning to use them is rarely a quick and easy process. However, recent research (Day, 1988) showed that representing simple computer commands in alternative ways makes it easier or harder to learn and use them. Subjects learned six simple editing commands used to move the cursor around the display screen; the commands were taken from an editing system unfamiliar to the subjects (Emacs, developed by Richard M. Stallman at the MIT Artificial Intelligence Laboratory). For example, the command *B* moves the cursor back one space. The commands and their definitions were displayed in standard list format or in a spatial format, as shown in Figure 2. Note that both formats used the exact same command letters and definitions but differed in their spatial arrangement of this information.

Subjects studied one of these displays and later solved a series of cursor-movement problems like the samples shown in Figure 2. They saw simplified computer screens consisting of dashes to indicate locations for potential characters and had to specify the common (s) needed to move the cursor (the small filled box) from its current location to a new location (indicated by the asterisk). For example, the current answer to the first sample problem in Figure 2 is F, which moves the cursor one location to the right. Subjects who studied the spatial representation were more accurate in this task than those who studied the list. Furthermore, they were more efficient. For example, the second sample problem in Figure 2 can be solved with either four keystrokes (*BBBP* or *PBBB*) or two keystrokes (*AP* or *PA*); subjects who studied the spatial format used fewer keystrokes on such problems. Thus, simple alternative representations of the same commands affected subjects' ability to use the information in an accurate and efficient manner. The spatial representation is more effective because it explicitly reflects the way the information is to be used--to move the cursor in various directions and across various distances. In general, it is important to match the form of a representation to both the nature of the information itself and to the nature of the task to be performed (Day, 1988).

Data Analysis and Problem Finding

Although most students study science in high school and college, can they think scientifically? Surely they learn about taxonomic systems in biology, formulas in physics, and the periodic table in chemistry. But can they take some simple evidence, analyze it, find its regularities, form and test hypotheses, and suggest useful future work? To study these questions, we give students a small set of data from a simple experiment and ask them to extract some basic results (Day and Diaz, 1988). Providing the same data in alternative representations affects their ability to solve simple problems. More interestingly, though, such representations also affect their ability to find and then solve more subtle problems embedded in the data. Subjects in the favorable representation groups, then, look as if they possess greater "scientific talent." In this and all experiments reported here, assignment to representation conditions is random, so *a priori* individual differences in scientific talent cannot account for these results. Thus, certain representations may potentially be used as a powerful tool to facilitate scientific thinking.

Overview

In the experiments presented here, we could dramatically affect what looks like the "academic ability" of students, simply by using alternative representations of the same information. We could increase or decrease students' ability to perceive chemistry molecules, to understand the function of hardware units, to solve text editing problems, and both to find and to solve data problems. Note that the alternative representations effect has considerable generality, for it extends across several cognitive processes (perception, understanding, problem solving, problem finding) and across several content domains (chemistry, physics/engineering, text editing, and data analysis).

Implications for Understanding and Fostering Academic Talent

The alternative representations approach holds some interesting implications for understanding "talent" and for considering educational practice for both talented and (presumably) untalented students. The experiments reported above show that we can make good students *look* more or less talented in a given domain, simply by giving them certain representations of key information. Perhaps what sets talented students apart from the rest is that they already know how to represent concepts in many ways and can select appropriate representations across a variety of tasks. Thus, appropriate representations may provide a general key to deeper comprehension and insight.

This somewhat unorthodox view of talent can be understood more fully using an analogy from ethological research. Ethologists observe animal behavior in naturalistic situations to determine what triggers responses. For example, male three-spined stickleback fish threaten other males who enter their territory by going into a characteristic attack position (assuming a vertical position with head down, tail up). It turns out that only a small part of the intruder elicits the attack position--its red underbelly (Tinbergen, 1951). In the language of the ethologists, the red "releases" attack behavior. Humans are obviously much more complex than fish and certainly respond to a richer array of information in their environment. Yet perhaps the ability to use alternative representations similarly "releases" or "unlocks" the complex processes of comprehension and insight. If so, then instruction might well include alternative representations of important concepts and thereby identify more individuals as talented.

Using alternative representations during instruction may well facilitate comprehension and insight across academic domains. If students thereby achieve some initial success with course material, perhaps they will not fear science, may become truly engaged with the ideas, and perhaps even consider pursuing a scientific career. It may also help to provide instruction about alternative representations themselves (such as sentences, lists, outlines, trees, flowcharts, graphs, and pictures) to identify their general properties and describe how they can affect various tasks. Then students can more judiciously select representations to facilitate finding problems as well as solving them, and, in general, facilitate their ability to think academically and scientifically. In this way, we may discover that more people have the potential for academic and scientific "talent" than we currently recognize.

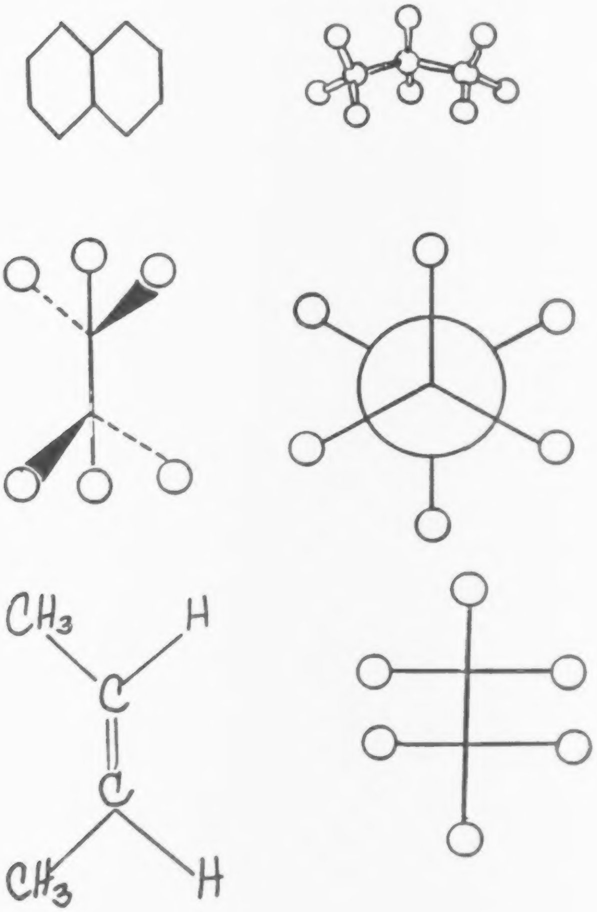
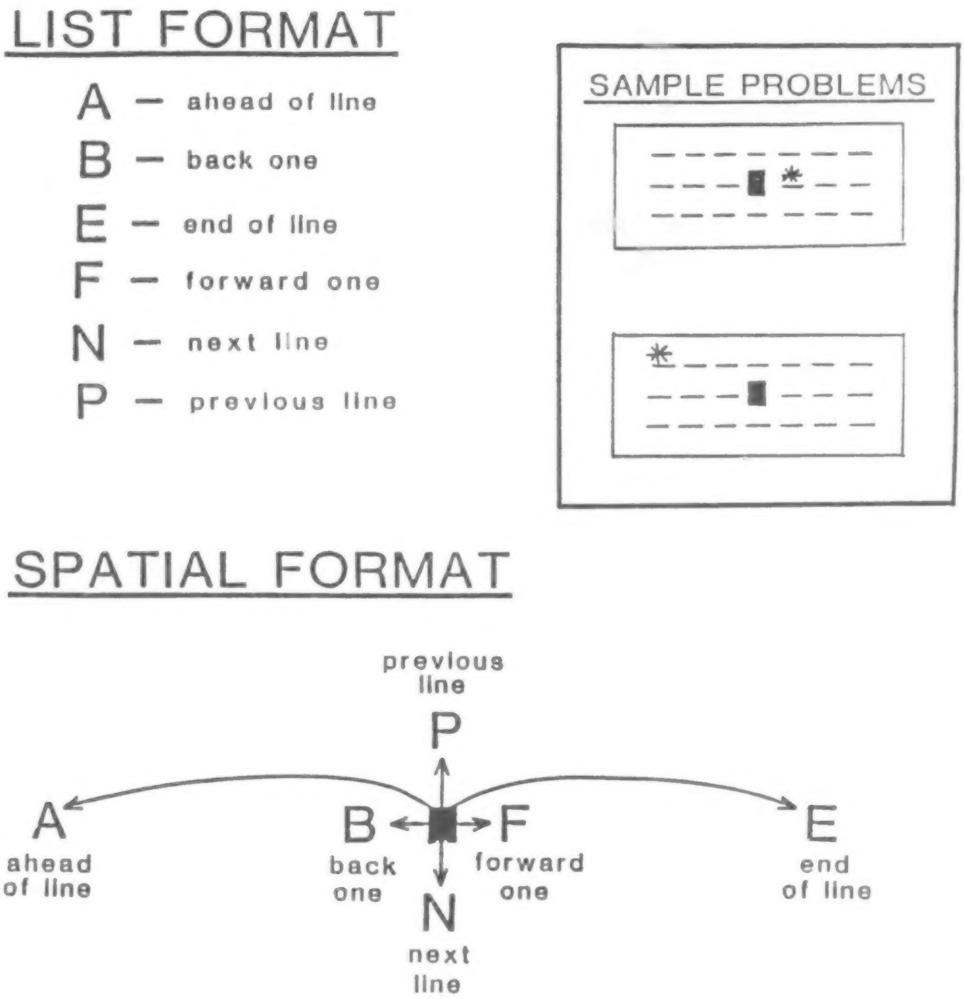


Figure 1 Representations used to display three-dimensional chemistry molecules in two-dimensional space. These representations (and others) are commonly used in organic chemistry textbooks.

Figure 2


LIST FORMAT
A — ahead of line
B — back one
E — end of line
F — forward one
N — next line
P — previous line
SAMPLE PROBLEMS
SPATIAL FORMAT
previous line
P
A
ahead of line
B
back one
F
forward one
E
end of line
N
next line

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Discussant Reaction: Cognitive Theory of Academic Talent

Edward F. Zigler

We have just heard a verbal presentation of what I found to be an absolutely excellent paper. But I'm supposed to be critical and analytic. Since I have wrestled with these same ideas for a good long while, I think I will present some old and some new thoughts that came to my mind as I read the paper. In certain ways you are going to find my views somewhat more optimistic than those of Perkins, and in other ways more pessimistic.

In a way, the paper is disappointing because the person seemed impassible. There is no mention of one of the most interesting developments in the field of intelligence, namely the social context in which cognitive development takes place. We are learning that people in different societies, different cultures, and different subcultures within a society exhibit very different intellectual profiles. Absolutely fascinating work has been done by Cole, Scribner, and Bruner. In fact, I advise Dr. Perkins that when he returns to Harvard he might chat with Gerry Lesser, who did that wonderful work some years ago which demonstrates profiles of abilities within different ethnic groups. This approach takes us away from the notion of superiority or inferiority, and takes us to where we probably ought to be in the biologically oriented behavioral sciences, namely as profile theorists. Actually, Regina Yando, Vicki Seitz, and myself advocated such an approach several years ago in a monograph.

Not only did I not find the social context, I didn't find the biological context. I do think that the future study of intelligence is going to focus more and more on the biology of learning and the biology of intelligence. It's been a long time since we read in Hebb's textbook about the notion of intelligence A, and we're still trying to unravel the phenomenon of capacity. I believe in capacity, in part because of my many years of working in the area of individual differences. Although there's been a longstanding argument over whether or not capacity is worth having as a construct, I've come to agree with Brendan Maher, who says that it's an easily operationalized construct. The phenomena is as follows: you give two people with different capacities the exact same environmental input, and one performs differently than the other. That's the operational definition of what we refer to as "capacity." Some of the most interesting work being done on this today is in the area of behavior genetics. When we look at the work of people like Sandra Scarr and Bob Plomin, and we see their findings on variations within families, I sense that we're beginning to close in on the aspects of what intelligence and its development are all about.

We have today three paradigms of intelligence to work with: 1) the psychometric paradigm; 2) the cognitive/developmental paradigm; and the most recent newcomer to the group, 3) the information-processing paradigm. If one simply takes the paradigms we have now, one can probably find approaches capable of directing current pragmatic efforts such as we are faced with here at the Talent Identification Program (e.g., research on selection procedures). But it still isn't that easy. Each of these approaches contains too many unresolved issues, too many points of contention for us to satisfy everyone.

For example, alluded to in Perkins' paper is the work of Jensen on *g*. Jensen is now defining *g* as fundamental efficiency of the neurological system. This is surprising, as though we've come full circle back to Galton, who worked with reaction times and was trying to develop measures that were independent of learning and tapped into the physiological nature of the organism. Later there came the old Ertl work with the flicker fusion test, which was trying to accomplish the same thing. Actually, there is some interesting work in this realm going on today. My hunch is that there will probably come a time in the not too distant future when we will no longer use intelligence tests. We will find some way of assessing the quality of the central nervous system. If this seems farfetched, I suggest that you look at the recent work of Hans Eysenck who says that he already has such a measure now. I'm not as convinced as he is, but at least he's on the right track. Willerman of Texas is doing much the same thing. We are some day going to be able to get away from the bias in tests simply by tapping into a person's physiology, to get at what Hebb called passive intelligence A.

I must confess that I was taken aback by the amount of space that Professor Perkins gave in his paper to the *g* versus *s* argument. I think that it is way too late in the game for people to be arguing *g* versus *s*. I find myself in the camp with George Miller and Sandra Scarr, each of whom have written devastating critiques of Howard Gardner's work. We are now aware that there is *g* and that there are also *s* factors. We have positions in the middle, like Vernon's with his hierarchical group factors. All of this is now known, and to bring it up again when we have so much else that we can legitimately study and debate is a waste of time and energy. They are both right, and any complete model will have to incorporate both of them.

The problem with *g* and *s* is that they are tied to the psychometric paradigm. They come out of tests and the analysis of tests. Unfortunately, we've convinced ourselves that the psychometric approach and the cognitive/developmental approach are different. The fact is, they are not that far apart. Using different types of measures, they both tap into the cognitive processing of the individual. While the argument goes on, the work by Kaufmann and others indicates that the correlation between those two types of measures is about .7, which is pretty high.

As for my colleague Bob Sternberg's triarchic model, and I certainly have a great deal of respect for Bob, I feel that it is simply too early in the day to understand just what meaningful information it is going to add. I do agree with David Perkins' assessment that the triarchic model may not be any more predictive than the psychometric measures we already have. However, this is an empirical issue, and Bob Sternberg has a new test forthcoming, so we'll have to see what the results are. I refer you to a very telling critique of Bob Sternberg's theoretical formulations by Neisser at Emory, who calls into question whether or not the triarchic formulation has the formal characteristics of a theory.

And now I slip into my own predilections and my own prejudices. I number myself among those who've taken the cognitive developmental approach to intelligence, its genesis, and its growth. I think that David Perkins is probably right. Of late Piagetians have fallen on hard times. But they're not nearly as hard as Professor Perkins would have us believe, so it's premature to sound the death knell on Piaget. The fact is that ever since John Flavell's presidential address at SRCD, we have been aware that the system works better in individual domains than it works across domains. Problems of horizontal and vertical decalages have caused problems with the overall theory, as David pointed out. However, we're working on these, and I continue to find a great deal of value in thinking about the human being as moving from stage to stage to stage, not only in cognitive development but in physical and emotional development as well.

One difficulty is that Piaget has captured the field so completely that many thinkers are not aware that there are other developmentalists who have made equally valuable contributions to our understanding of intelligence. I think in particular of Vygotsky, who emphasizes the forgotten social context. Also my own mentor, Heinz Werner, and his three-stage model of global to differentiated to hierarchic integration. His model is a precursor of modern work. For example, not very many miles from Harvard is my old colleague Bernie Kaplan, whose book represents how Werner's model fits language development. I myself have been using developmental models for a long time to try to comprehend individual differences. They make it possible for me to quickly shift my attention from the retarded to the gifted group, because the relationship of retarded to average functioning is exactly the same as the relationship of the average to the gifted level.

I think that there are two very important phenomena which illuminate what we've been talking about this afternoon. They give us some notion of where to look for precursors of giftedness as well. One has to do with the rate of cognitive development. For an operational definition of stage of development, I've used the MA (Mental Age) for 30 years. We know that people move through MA stages at very different rates. Someone moving through these stages very rapidly is a potentially gifted individual. There's nothing brilliant about someone observing that if you cut a pie into two uneven parts, the sections are not halves. What's special is that it is noticed by a six year old. If a 15 year old said that, we wouldn't be impressed. This brings me back to our old friend Galton--everything seems to double back to Galton. He was a phenomenal little child. He could read and write at the age of four, and attained a scholarly understanding of *The Iliad* and *The Odyssey* by age six. The people who knew young Galton didn't think there was anything amazing about him, since any respectable school graduate could do what he did. What was amazing, however, was that he was so young to achieve so much. Traversing the stages of development very rapidly is item one to look for in a precursor.

The other phenomenon can't be used as a precursor; it has to do with individual differences. People do not wind up at the same final level of cognitive development. Plenty of people never make it into logical operations. And now we're talking about a post-logical operations stage. So what we're looking for is people who go through the stages very rapidly and wind up at an asymptote that's much higher than average. These are our gifted individuals. I have just begun testing a model on Duke TIP students. If my model is right, we should be able to compare gifted people with older individuals who are their MA mates, and show that their cognitive functioning and motivational characteristics are just about the same. We've done one study that supports this hypothesis, so at least we're on the right track.

Let's move to another problem, the creativity versus intelligence issue. This has also been around for a good long while, so we're all fairly conversant with it. I find myself pretty much in agreement with Perkins that it looks like intelligence is necessary for creativity, but not sufficient. Still, if something is necessary, it at least gives us a place to start. That's why when we look at giftedness we continue to have to rely on what's necessary, namely, a very high IQ. Unfortunately, we've never been able to get a very good handle on creativity. There is a body of work which cuts across the psychoanalytic camp, the cognitive camp, and the developmental camp. I refer you to a book by Arieti, *The Magic Synthesis,* where he attempts to show that a combination of some earlier forms of thinking, in line with the ego in his psychoanalytic term, gives you creativity. If you picked up Kessler's book, *The Act of Creation*, you could find that same appeal, that creativity is thinking in very divergent, unusual kinds of ways.

Developmental thought gives us some leads here. There are certain phenomena of thought that characterize the very young child which are lost in later development. It would be wonderful if we could access them. Synesthesia is a good example. In research on people's perceptions of the color of the sound of a trumpet, we find that every kid is better at synesthesia than every adult. This and other phenomena seem to be characteristics of the early forms of development which somehow drop out of the system. Werner and other developmentalists have said that the combination of the lower forms with the higher forms results in a creative individual. If you just use the lower forms, the result is a schizophrenic. In Piaget's telescope model of development, those early forms don't just vanish, they are embedded within later forms. If we could find some way to break those early forms out and make them accessible so they could operate in combination, we'd have a storehouse of creativity.

I've always been troubled by the assertion that IQ tests don't measure creativity, because most definitions of creativity sound very much like what we ought to be saying intelligence is. I find myself in agreement with Quinn Nemar. In his presidential address to the American Psychological Association many years ago, he made a point that I've made in some of my writings as well: we need measures of creativity in our intelligence tests. The problem is that creativity is a very unusual, very rare event. A highly creative person is very rare, and the standard measures that we construct are not very good at signifying these rare events. They're good at gettng everyday events. So this means that there's still plenty of room for people to try and study what we mean by intelligence and what measures we need to assess it. Our first sound intelligence tests, beginning with Binet, are really very arbitrary. We've been almost victimized by their success. We can look at their failures, as David Perkins has chosen to do, and think about new measures that will encompass creativity.

One other phenomenon that I found inadequately covered in Perkins' paper was the whole issue of motivation. When he does discuss motivation, he discusses it in a very thin way, by pointing to the work of Bloom. Bloom focuses on all the work and energy and effort that parents and kids put into their work. To me, that's a matter of extrinsic motivation; that's when you're programmed to become a genius. That isn't what most geniuses and creative people really look like. I would be much more interested in a discussion of what is called effectance motivation. With this impetus, people work diligently for the sheer joy of using their own intellect. I've studied this concept, usually within the construct of humor. I've learned that we most enjoy jokes that we have to work to understand. To me, the nature of intrinsic motivation, where we have to do most of the work, rather than the kind of extrinsic motivation that Bloom and Perkins have emphasized, brings us closer to what giftedness is all about.

We've heard from both David Perkins and my old colleague Ruth Day about efforts to make people perform more efficiently. This is certainly possible. There are skills and pedagogy which improve performance. Of course, those of us who've been around for a while remember Moore's talking typewriter and the ten thousand other things that have come along in the last 30 years which guarantee to make everybody smart. I've become pretty skeptical. I think about the work in mental retardation of my colleagues Butterfield and Belmont in Kansas. They were working on that little monkey list that shows up in Perkins' paper, but there was very little generality. We were not successful in making retarded individuals much smarter. There is a new book by Herman Spitz, who reviews 100 years of efforts to make retarded persons more intelligent, all of which have failed. Does that mean we quit trying, that we don't try new inventions? No, of course not. To me, these are empirical issues. I'm just saying that I need hard evidence before I'll be terribly convinced that people can be trained to be much smarter in any general sense.

This brings me back to the precursor issue. David Perkins seems to be saying that we have in our TIP students saplings, but he would like to get back to the seed. I look to the work of behavior geneticists and say that we don't even have to wait for the seed. We know the best predictor of an individual's intelligence before he or she ever arrives at Duke, or comes into this world for that matter. That is the midpoint of the parents' IQs. It isn't a perfect measure, of course, and there is still a lot of room for environmental influence. But, it is simply too strong an indicator to ignore.

I want to pick up the competitiveness issue. Should we start approaching intelligence and giftedness and creativity the way we approach basketball players? We're all aware of values that were discussed in Al Trivelpiece's keynote address. We're all very sensitive to the charge of being elitists. There are two responses to this charge. One I reject out of hand, and that's the one of people like Renzulli and others who say that everybody is intellectually gifted and let it go at that. I don't think that's acceptable. I'm so immersed in a lifetime of studying and respecting individual differences, wherever they might be, that I simply cannot tolerate such a homogenization of the human race. My hunch is that we're going to be stuck with the charge for awhile until we get better measures of IQ, so the second response is just to wait. We can try measures that TIP uses, like the SAT, which is probably correlated respectably with IQ. That doesn't mean we shouldn't continue to look for better measures. If we don't, then I think the charge of elitism is appropriate.

We can refute this charge right now if we commit ourselves not just to the gifted, but to that vast array between giftedness and retardation where most of humankind is. My knowledge as a developmentalist who has learned something about cognitive psychology tells me there's absolutely no reason on this earth why children shouldn't be learning to read by the age of 7, why the dropout rate is so high, or why schools are doing such a poor job with our young people. It is imperative that we think in terms of upgrading education for all children in the U.S. By so doing, we will allow a higher number of children to exercise their giftedness. We will also guarantee a generation who can read and who are literate in math and science. This is every bit as important as having that handful of great intellectual leaders.

I would also like to make a comment that I've stolen some from my colleague Fran Horowitz. We must not think about children solely as little cognitive systems and worry about how to maximize those systems so we can have great mathematicians and scientists in the next generation. We must recognize that education and cognitive development sit within the body of a child who is much more than this. If you really want to produce more geniuses and better kids in general, you're going to have to look beyond education and whiz-bang intervention efforts to make kids brighter. You're going to have to look at what kind of child care they are receiving. You're going to have to look at what kind of health care they get, what kind of nutrition they have, and how strong their families are. So beyond focusing on the whole population of children, we must focus on the whole child.

I would like to bring up another concern I have about what happens to the curiosity, the inquisitiveness that is natural to the very young child. All of us who work with children at the ages of 3, 4, and 5 know that everything is a question to them. They're always looking for problems, they're always looking for things to take apart. Give them something they can't take apart, and they'll find a way to take it apart a 12 year old wouldn't begin to try. What happens? I'm a veteran of the post-Sputnik era, when Admiral Rickover said, "Of course the Russians are ahead of us. They teach their kids engineering and their school days are longer. All we're doing with our children is teaching them finger painting, eight months a year. We've got to get back to basics. More reading, writing, arithmetic. Stop this gym, this acting, stop all the things that enrich the mind and the human being."

Again, I'm indebted to Fran Horowitz who suggested that we've come this way before. As I look about the country, I find that those who don't know history are forced to relive it. We are reliving it. The response of this nation to the first report, *A Nation at Risk*, and the dozen that came after it has been exactly what happened after Sputnik. How do you make the days longer? How do we keep kids in school more days a year? How do we get back to the "hard core" effort? We're even seeing this emphasis come down for very young children. I attended a conference at Yale a few months ago which resulted in a book by Lynn Kagan and myself called *Early Schooling: The National Debate*. Today we are seeing some schooling for four year olds that looks like the first grade has been moved down to age four. The play, the curiosity, the self-discovery of children are being wiped out by people who think that the only way you can teach youngsters is to sit them at desks and yammer at them, or have them fill out little workbooks. If you want to know exactly what I'm talking about, I refer you to the book that says it all in the title--David Elkind's *Miseducation*.

Let me conclude by saying one final thing about which I'm somewhat pessimistic. One of the big problems we face is the problem of school change.

We have some very brilliant workers working on this issue, but it's still far from solved. I'm friendly with some of them. I just came back from a meeting in Seattle with John Goodlad, who's one of the great thinkers about how to get schools to change. Seymour Sarason, my colleague at Yale, has been writing about this for a good number of years now, and pointed out why the new math fell on its face. Part of the problem is that there are sixteen thousand school districts in the country. How in the world do you bring change into a polyglot system of that kind?

My position is that if we had leadership--not a school basher, but a real leader--helping schools do what schools ought to be doing, I think we would see progress. The system does work. When I was in Washington as Chief of the Children's Bureau, I decided it would be a good idea to have education for parenting in schools. I was very worried then about teen-age pregnancy. I thought that teaching kids what parenting was all about might help. We developed a curriculum, distributed it, and it's now used in 3000 schools in America. It's not in all 16,000 districts, but 3000 isn't bad. In New Zealand, exactly the same curriculum is used in every school. Apparently, it's much easier to disseminate nationwide programs when you have a Ministry of Education. I believe we could have the same success in the U.S. with the proper leadership.

I want to end on an up note. I have been reading Arthur Schlesinger's new book in which he points out that societies have waves of progress and regressions, zeniths and nadirs and back. Those of us who have seen the good, innovative times of the '60s, and the very bad times of the '80s might take some heart from Schlesinger. This great historian's view suggests that America may be on the verge of another upward swing. We heard from our friends in Washington that the window is open; I believe that's right. We're all going to have to work very hard to try and scurry through that window while it is open, but I am optimistic we will be there on time. In conclusion, I think it's appropriate for me, on behalf of the audience, to thank David Perkins for an absolutely excellent analysis of the problem that we are here to face.

THE IMPORTANCE OF DEVELOPING LEADERSHIP POTENTIAL OF YOUTH WITH TALENT IN MATHEMATICS AND SCIENCE

Kenneth E. Clark

This conference is addressing critical issues with regard to the identification, motivation and development, and the tracking of academic talent. Important matters of policy rest on these discussions. We have heard again and again of the vital role of the talented in the fulfillment of the world's plans for a better life and a better society. Unless we identify and nurture this portion of each generation we will fall short of our goals, for our societies must rely on this talent for the solution of its problems. I am delighted to be a member of this group addressing this important issue and fully support its purposes.

I make this introductory statement because the theme of my talk is somewhat different from what many of you have been considering. I will argue that the search for and development of talent in science and mathematics must not be so circumscribed that every young person found with that talent be captured for science and mathematics careers. No one has suggested that, but the current scarcity of talent in these areas surely tempts us to be zealous, maybe too zealous in our protection and use of this rare talent. My point will be that persons with these talents also possess other talents that must also be nurtured, and that our society will gain more if many of our very best youth commit themselves not only to excellence in science careers, but also prepare for broader roles in the betterment of our society. I will base my talk partly on psychological data about human qualities, and partly on a growing set of data about leadership qualities and how they develop.

My hope is that attention to other talents will help us to broaden our thinking a bit.

I am an industrial/organizational psychologist interested in the ways in which people choose lifetime careers and in the way these careers develop. I think it might be useful for all of us to keep the discussions of these three days within a perspective that draws on what is known about human qualities and the way they emerge or develop. I will give you a number of generally accepted propositions.

1. Human characteristics vary. Most people are near average. We all know that well--in fact, the differences among persons is the very reason for our conference. When psychological measures of various attributes are developed and use to obtain scores on populations of humans, the form of the variation generally matches the Gaussian curve, with most measures clustering around the middle, or the mean, with fewer and fewer measures being found as one moves farther and farther from the mean. Most people are near the average on most characteristics. When we start searching for persons who have the prospect of truly advancing knowledge, we must talk in terms of relatively small numbers.

2. All socially desired qualities are positively correlated within a society. It is not our business today to examine why this is, but the statement is true for all societies and all socially desired samples--the correlations are higher than most of us want to believe--generally ranging around .30. When the qualities are school-related, the correlations are much higher; when they are experience-related, they drop. The implications of this phenomenon are obvious. The talented in mathematics and science are often talented in other areas as well. If we draw

out the science-talented, we draw a larger than average proportion of persons talented in other areas as well.

3. If talent is paramount, we cannot be egalitarian. Great talent is not distributed evenly over various strata of society. More talent is found among the most prosperous; least among the poor. However we shape our programs for the talented, we will be accused of elitism and discrimination. Even if our purpose is to give equal opportunity to every person from every walk of life, we will not end up with equal representation from each walk of life. If we insist on that outcome, society will pay quite a price in lost talent.

4. Great talent can be found in all segments of our society. Even when substantial differences may be found between groups, the differences within groups are always greater. That is true for all valued human qualities. If our society restricts its opportunities only to the groups already evidencing success, we will pay quite a cost in terms of loss of talent. We will also have violated one of our fundamental values.

5. Talent is not something that is 'just there' waiting to be found. One need not enter the argument about heredity versus environment to come to this conclusion. The simple point is that talent in science emerges and is identified only as exposure to the subject matter occurs--whether by teaching or by exposure to problems needing solution. Only when opportunity presents itself will such talents be discovered. Only when sufficient challenge is present will the quality of the talent be estimable. Only as adequate guidance in learning is available will it be possible to discover the ultimate limits of talent. This point emphasizes what many of you have already said--that in the absence of challenge one cannot even guess at the loss of talent in a society.

6. Talent that is undiscovered or underdeveloped is our major problem. Society does not improve by virtue of the *latent* talent of its members, it improves by the works--their actions. To translate talent into useful acts, into creation, into change, into discovery is our goal. For a person to lead a useful life that takes advantage of latent talents to the utmost requires more than just the discovery and development of talent. It also requires a system that provides assignments for work, support for that work, increasing challenges, opportunities for increase in scope for responsibility, opportunities to take on tasks from the start, opportunities to stop and reflect, and opportunities to develop strengths into greater strengths, to discover one's weaknesses, and to find how those weak areas may be handled so as not to set limits on one's achievements. If we do not provide these opportunities and challenges, we again pay quite a price in loss of talent.

7. The choice of one's life work is among the most important choices an individual makes. That choice determines in large part one's identity, one's self-image. It says something about one's life's aspirations, and the values held highest. Choice of career can be predicted twice as accurately by inquiring about one's preferences for specific work activities as by measuring one's abilities. Intrinsic interest in a given type of work will more likely lead to creativity in that work, and continuance of employment in that line of work.

8. Learning by top performers is lifelong. A very high proportion of learning that undergirds useful performance on the job is acquired after leaving school. It is as important to continue learning on the job in order to be effective as it is to learn all those needed bits of knowledge and the skills that are taught in our institutions of learning. We have seen in our society and others that much of what is learned on the job can be destructive---by undermining commitment, by reducing aspirations, by heightening stress, or by sheer dispiritment produced by oppressive environments. Fortunate are those persons whose work continues to interest and to challenge them throughout the work life, and those societies that provide for their people such interest and challenge.

9. Highly successful adults change a lot during midlife. Human qualities do not develop and mature only during the formative years--say up to age 25--and then stay the same until the ravages of life are seen in senile deterioration. One's abilities, character, and personality change through the midlife period, sometimes resulting from, sometimes leading to distinctive shifts in jobs, locale, family circumstances, and values. Without the forces leading to growth and development, the midlife period may become one of dullness and misery. For most people, responding to new assignments and challenges, being given opportunities to be innovative and creative, and even living through personal crises and hardship helps them to redefine their values and goals making their lives continually interesting.

The preceding statements did not come just from studies of mathematicians and scientists, but you can see their applicability. Instead, they came from studies of students; of tradesmen; of professional persons; of salesmen; of leaders, executives, and managers; and of the work forces that reported to them. Some have come from recent studies aimed at understanding how effective leaders get their jobs done, and how they learned to change their behavior dramatically in order to become more effective.

These propositions remind us that we must be concerned not merely with the identification of those youth who demonstrate potential for high performance in science and mathematics. We must also give them the opportunity to develop these talents, and all the other talents they possess. If large numbers of these youth are to pursue careers in science, they must not only know that jobs exist, but that such careers will be fully rewarding to them--in money, satisfaction and challenge. Every opportunity must be provided to learn more, to discover, to respond to problems in new and creative ways. If we truly prize the talents of our people, we must provide every opportunity for the continued development of talent throughout the life span. Our society probably does this better than any other society, but we all know how poorly the system works for many people.

Every society has addressed in some way this issue of use of talent. Since the beginning of mankind, life for each human has improved only as people have joined together for their common good. The quality of life improved as new tools were invented, as ways of controlling the environment were discovered, and as the special capabilities of individuals were exploited. The craftsmen soon gained stature as their crafts made life easier. Leadership and authority were yielded to the strong and powerful, or to the wise, or to those born to the purpose, or to those who were seen as chosen. As civilization progressed, the young were taught the skills and crafts of the parents. For those youngsters born of the leader, or later, into royalty, training for leadership began almost at birth. Any youngster could have told you what he (rarely she) was going to be when he grew up--he would take over his father's craft. The mason's son became a mason, the carpenter's son a carpenter, the prince would become a king.

The American republic was founded on a new set of principles--principles of freedom and equality that gave high priority to opportunity, and to the idea of an open society--a society in which any person would be free to seek any goal, with no preferment to any. This new government also denied the right to inheritance of positions carrying power and authority. And the old-country laws on rights of the first-born were abandoned. The freedom not to follow in one's father's footsteps--critical to establishing an open society--also meant the loss of rights of the eldest son to inherit the father's position of power and authority. In one bold step, the new Republic declared an open competition for all positions in which the incumbent was authorized to enact laws and govern in the name of the people.

Those of us at this conference take for granted some of the unique aspects of our society. We have a few unspoken assumptions: that there are talents to be developed throughout all levels of our society; that these talents are of great value, and must be discovered and used if our society is to survive and prosper; that possessors of talent are free to use these talents in any way they want; that a wise society will assign its rewards and gratifications so as to assure that a sufficient number of them choose activities that will promote society's most critical goals.

Our founding fathers included plans for a program of public education in which all citizens became informed so as to give meaningful consent to being governed. All citizens were to be able to read and write, to have a minimal sense of history and the values upon which this society was founded and to understand their role in yielding power and authority to a group of leaders who would always be accountable to the electorate they served.

These wise men also recognized that those elected to hold the reins of government as representatives of the people would also need appropriate education. If young members of royal families had needed years of preparation before ascension to the throne, so, too, would an entire corps of potential leaders in the new Republic. These founding fathers were the elite of their times; their expectation surely was that a similar elite would be maintained and prepared for positions of leadership by higher forms of college education of the sort they had experienced.

The task of governance has become more complex as those who lead have neither royal blood nor a divine right to sanction their every act. And if consent of the governed is to be expected on issues of all sorts, solutions attained solely by the display of force will not do. Gaining acceptance of decisions--not just enforcing them--requires that leaders not only be highly intelligent, but also deeply committed to the cause of freedom, understanding of the ways of compromise, and endowed with enormous patience and forbearance.

Over the years, our society has asked our educational institutions to help in many ways. After Sputnik, our schools and colleges were central in the race to put a man on the moon. They were the major battle grounds in the war over civil rights--almost one hundred years after the slaves were freed, and almost fifty after women were given the vote. They are providing the major base for that research and development that undergirds our efforts to compete worldwide with our products, now that other nations have become competitive. When business or government puts up the support money, our schools and colleges turn to preparing more specialists in given fields, or turn to their research and scholarly interests into the desired areas of study.

We have come to expect that the educational system will change the direction of interests of students to match the needs of society. We have seen programs to give stipends to graduate students if only they will study mathematics or physics or molecular biology or engineering. Our news columns fill with statements from the Secretary of Education telling us all what students should study, and what he thinks a good curriculum should look like. These admonitions are drowned out by the multitude of messages with money attached--how much a Harvard MBA earns in his first year on Wall Street--what new BS's in engineering get--how much of a stipend a bright MD-PhD aspirant can receive. Our students are not stupid--they read society's priorities correctly--and go where the money is, especially to where the highest paying jobs are. Their ideals and their self-knowledge about interests and talents will moderate their responses to the message about priorities, but exhortations do not.

This conference is concerned with better use of the talent of the next generation so that we may strengthen science and technology in the service of mankind. I want you to add to your thinking the goal of strengthening our leadership, in the hope that our society might be better governed, and that leadership might be more effective. Both quests involve the same target population--the best and the brightest of our youth. Are these goals compatible, or is my suggestion a distraction?

When I speak of leadership and leadership responsibilities, I am speaking not so much about being president of the United States or president of a major corporation as I am about several millions of persons who understand what our society is all about, who cherish its values, and who see the defects that need correction, and the cracks in the system that interfere with effective functioning. Some who resonate within themselves to the near-misery of many of their peers, and who seek to improve the system to reduce that misery. These are the ones who make a difference. Some people call them change-agents. The correct word is leader--creative leader--an inducer of change for the good of all.

Warren Bennis interviewed 90 CEO's of major corporations. He was surprised by the diversity among the ninety. There were some common elements, but no one possessed all the good qualities; many who possessed some of the elements were in no way leaders. That has been one error of the past--to assume that leaders are alike. People we view as leaders say, "I had to learn a lot." Many become leaders much to the surprise of those who knew them in earlier years. Highly successful scientists are not out of place in such a population. In fact, they stand out.

McCall, Lombardo and Morrison asked top leaders in the corporate world to describe the experiences that taught them something; they reported: having to do something new and difficult, maybe on their own, a jump in the scope of the job, a challenge to save a failing business unit, starting up something new in strange surroundings, having to review their own goals and achievements while wondering whether they have been sidetracked or passed-over, being assigned to work for a four-square bastard, living through personal trauma, deaths in family, or divorce. These events teach--and change behavior--and seem to lead to improved effectiveness in leadership.

McCall and his group also examined what was learned from such experiences. They found that particular experiences taught particular things, and that those who had the most trying times usually learned the most. The learning often was a learning to balance--to balance self-confidence against an awareness of one's weaknesses; to balance a willingness to do some things one's self, while also learning to delegate well; to balance the goals of the organization against the needs of the persons in it; to balance collection of information from all sources, but be able to make decisions at the right time, before all possible evidence is in.

Studies like these of the lives of top leaders in industry say that good leaders need to learn, to be tested by experience, and then to examine and review what they learned. Those who did learn are seen to have developed an unusual sensitivity to the way the world and its people operate, with a sensitivity especially to those behaviors that result in one's gaining the respect and trust of others. Equally bright persons having similar experiences differ enormously in what they learn, i.e., in how much they change their own behavior in order to become more effective in leadership roles. Some never learn to change their behavior, and thereby set limits on their own growth and success.

Positions of leadership require certain prerequisite abilities: good mental functioning including a good memory, good problem solving ability, and the abilities to communicate and persuade; excellent cognitive functioning; and an ability to see interconnections, to notice parallels, to spot inconsistencies . . . to find ways to get a handle on a seemingly intractable problem.

These are the qualities we look for and that we seek to develop in our young scientists. These qualities are well developed and nourished in good pre-college educational programs and in an undergraduate education of high quality. But this list is incomplete for leaders--for the leader who is to serve best must also understand our traditions and our highest values, and must somewhere have acquired a commitment to put the good of all, and the preservation of our most fundamental values at highest personal priority. It is not also incomplete for our best scientists?

Would not our scientists and mathematicians be better off if a component of their undergraduate education was identical to that for persons electing to prepare for leadership? Should we ever say that we would rather have more scientists than have better leaders? Should those persons talented enough to make major contributions to science and mathematics ever be asked to avoid their citizenship responsibilities and the likelihood of leadership roles?

For my money, the four years of undergraduate education should be full of challenges. Challenges that are real, in that the student is expected to perform at the highest level of competence in a wide variety of scholarly and scientific efforts. By the end of the four years the student should have learned something--but no test is adequate to measure the learning I hope for. I would ask that every graduate know by the end of the four years his or her strengths and weakness, the domains in which talent is great and where it is least, and the work that excites and entrances, as well as the work that seems boring or stultifying. I like to think of these four years as a testing period where the consequences of success of failure are minimal, save as they inform the individual about how to have a satisfying and successful life.

So the best college experience by my standards is the most varied one. Let me tell you that as an arts college dean for twenty years I reviewed thousands of undergraduate programs. The narrowest and least challenging programs were more often elected by those who avoided mathematics and science, often because they had tried them and had done poorly. Some students majoring in science were pretty narrow, too, but most were not. Their interest in music, art, literature, philosophy, history, and political science was often almost as great as their interest in chemistry, physics, or biology. I can only guess--but you can all guess as well by reviewing the lives of colleagues in science--that those who do the best in science are also the ones who have the broadest range of interests. We have all observed that the students we admire most because of their interest in *our* disciplines are persons with such broad talents that they would succeed in almost any areas they elected.

I once heard an eminent scientist say that those who were good at science must by all means be a scientist. Other persons with less talents could take care of the rest of the problems of society, but, since science was the hardest to do, top talent should be used in science. Do you agree? I do not. Do we want the most difficult problems of the world and the relations among nations dealt with by persons who have not studied in the most rigorous and challenging of subjects? Or who tried studying them and found them distasteful or painful or too difficult? Would we not be better off if the capabilities for leadership of our most talented were also identified and developed as we developed their abilities to add to knowledge in science?

Before you answer that question, or think of reasons not to ask it, let me remind you of the nature of our society, and how it got that way. In the process of that review, some fundamental principles underlying our current institutions may become clearer.

Maybe governing a society committed to the concept of government with the consent of the governed was easier in the early days of the Republic, when the consenting process could occur within the four walls of a room, in a town meeting. As the franchise and the right to hold office has expanded to a much larger and more diverse population, gaining consent has become much more complicated. Today as citizens we struggle to live up to our ideals while every possible interest group forces its attention on us. As a result, we have too many purposes, too many items of agenda to attend to. How do we set priorities, how do we get on with the most important business?

With so many cries from diverse interests, the role of the leader becomes more critical. We need to allow voices to be heard, and then make decisions based on our values and priorities, not on volume. That requires leaders who can inspire us to commit ourselves to important goals, and who themselves can engender sufficient trust from others so as to have the power and the authority to do the right thing. Such leaders need to receive an excellent education, and then, as studies in the business world show, accept opportunities to learn, to test themselves, and then to act and to be judged by how well they have learned.

Would the demands placed upon leaders for preparation and for commitment be attractive to persons who find fascination in mathematics and science? Do you believe the two domains are incompatible? I remind you of the diversity among our youth talented in science. Many of them have interests and a sense of commitment entirely appropriate for a life of leadership. Would the world be better off if more leadership were exercised by the talented youth about whom we have been speaking in this conference? I think we can answer that question affirmatively.

Have you been thinking about productive scientists becoming politicians, and saying--what a waste? We must remember that leadership is exercised in many ways. America is a pluralistic society, with governmental organization and religious organizations, professional societies, private business corporations, voluntary community organizations, and all sorts of clubs, societies, trade organizations, and the like. In every career there comes a time when one wishes to influence the larger group--when the wish is to sell, persuade, convince, or at least have one's own way. Every individual with some ideas for making improvements needs the capability to communicate and convince others. Should we overlook the need for the best and the brightest to acquire these capabilities because they have great talent in mathematics and science?

You may have noticed that I am arguing for a new definition of liberal education: for an education that prepares youth for continual learning of all of the skills and capabilities required to accomplish to the fullest all of their life ambitions; for an education that sensitizes each individual to the responsibilities that must be accepted for improving the society in which we live. Too often, liberal education is defined as studying the past, of reading the classical writings, of being able to quote words appropriate to an earlier time. Small wonder our students and their parents want something more than that. But our school systems must change in order to help prepare for the leadership we require today.

Our educational system is admirably designed to help society find and develop the specialists it needs. When there is an increase in well-paying jobs for engineers, somehow the number of persons seeking engineering degrees increases, and the need is met. When our country began an ambitious space program, qualified people were found. When after World War II there was a need for many college professors, salaries went up, and qualified people began applying for the jobs. We are an adaptive society.

However, our educational system has not succeeded in preparing leaders. Does the fault lie in our schools and colleges, or somewhere else?

We are asked *ad nauseam* how was it that so many extraordinary leaders emerged at the time of our Revolution. The answer is--that was where the most exciting activity in the world was occurring. To use the vernacular, "It was the hottest game in town." Anyone would want to get into that act to help create an absolutely new government based on so lofty a set of principles? No other item had higher priority in the young Republic.

And later, do you remember how the greatest talent of the country was drawn to work on the atom bomb to get one before Hitler did--and later on space science to get to the moon before Russia did? Today, our young talent is drawn to research in semiconductors and in recombinant DNA and in the growing fields of application of these new discoveries. Many have recently discovered that careers in business can be exciting *and* rewarding, especially if their financial analyses and forecasts prove better than those of their competitors--although October 19, 1987, may have disillusioned a few!

Realistically, we cannot influence all talented young people to become scientists or mathematicians, even if they have great talent; nor can we persuade all of them to plan a life of leadership. In every generation some young persons want to be somehow different. All are not as ambitious as the persons in this room. Some however, are fully uncertain, and are easily influenced by society's campaigns. And there are enough flexible persons who do change to match the changing needs of society. As our needs for computer specialists increased, for example, hordes of students began preparing.

Students make their career plans first by examining themselves, mainly looking at their interests and their talents, and second by assessing the state of the world--namely the job market. The very best way to change student objectives is by increasing the availability and the attractiveness of lifelong jobs. Pay level is important, but opportunities for advancement and security for some are more important. A job that gives the opportunity for service attracts many. If opportunity for a lifetime of service is tied to assurances of high status and honor, and a bit of job security, few will turn down the bait.

Neither scientists nor leaders will emerge in sufficient quantity and quality in a society unless and until society rewards it, supports it, makes sacrifices for it, and gives it higher priority than anything else. Money is important, but for an idealistic youth, status, prestige and respect are critical.

A society in which we use scientific talent also requires leadership that understands science and how new developments occur. A society that can accommodate to the wonders of new discoveries is rare; new discoveries frighten most people, and often lead to movements that can only be called atavistic. Only a quality of leadership much more appropriate to our times can help our society restructure its myths and its institutions and realize the full potential of new knowledge for benefiting people.

How do we make all of this happen? Well, I say, first we must attract into leadership responsibilities persons with better talent and better education than we have seen so far.

Let us help students understand the necessity for identifying and nurturing leadership talent. A somewhat different look at history would help, in which the fateful decisions are somehow highlighted to show the knowledge available to the powerful at the time they exercised power (Herbert Simon has a computer program that does that for science). Such an analytical orientation might help us learn from history rather than merely reminding us not to repeat it.

Let us teach courses that inform about the qualities required in great leaders, the necessity for commitment, the importance of integrity, the necessity for clear vision. Let us also teach the skills of communication and of persuasion. Let us learn to relate better as humans to humans, recognizing our differing values and finding ways, by practice, for accommodating to them. A campus is a great laboratory for such learning.

Let us help students discover how to profit from experience. Provide laboratories in which they may exercise these skills both in classrooms for credit and in the student groups that assemble for various purposes.

Let us identify those who seem to possess the requisite basic capabilities who seem to be the best bets for leadership roles and encourage them to seek opportunities for development; to think of themselves as future leaders; call such persons to the attention of employers and agencies as persons of great general promise; give them opportunities to learn about leadership.

My thesis is that an educational program of this sort is precisely right for the talented youth who represent our best hopes for the future in science, technology, and mathematics. The ideal is a broad and liberal education that builds commitment and concern, an understanding of our social institutions and how they work, and that develops ability to engage the rigorous and analytical processes that characterize good science. Such a program will produce leadership for our nation not only in science and technology, but in governance and human relations as well. From this wonderful group of broadly educated scientists our nation and others can draw the leaders of the next generation with confidence, certain that they will know enough, and believe strongly enough to accomplish miracles.

Discussant Reaction:
The Importance of Developing Leadership Potential of Youth with Talent In Mathematics and Science

Earl H. Dowell

Let me cover the information in my written response briefly and then get on to some of the interesting things Dr. Clark had to say this morning. Dr. Clark's central thesis is that there are some very bright people studying science and mathematics and engineering today. This is true, and it's been true for at least a half century. However, recently there's been quite a shift within that spectrum. A major demographic change among undergraduates in the U.S. over the last 10 or 15 years has been that many more bright students are now studying engineering rather than science. Twenty five years ago the pecking order was clearly physics first, then mathematics, chemistry, biology, and so on. Now it's engineering, followed by biology, physics, etc. In any event, within this total spectrum there are some very, very bright students, disproportionately so compared to the general college population. I think it's fair to try to encourage these people to do something more than solve equations and make measurements in the laboratory. Shouldn't we encourage them to be leaders in the broader sense? Clearly, the answer to that question is yes.

How do we go about encouraging bright students to become leaders? Before addressing that question let me suggest how I think we're doing, or not doing so well. I will take as my examples the one that Dr. Clark said that we shouldn't take, namely CEO's in major corporations and Presidents of the United States. Those are not good examples according to Dr. Clark, and I think he's right in some ways, but he's wrong in another way. The way in which I suggest he's wrong is this: many of us might at one time have thought that we wanted to be the CEO of General Electric or we might have even wanted to be President of the United States. These people do serve as role models. What would a young person think looking at the presidential candidates today, with respect to wanting to be President of the United States? I don't know the answer to that, although I can hazard a guess. In any event, let's look at CEO's of major corporations and Presidents of the United States.

CEO's of major corporations. I've seen a couple of studies which suggest that about one-fourth, perhaps as many as one-third, of the CEO's of the Fortune 500 companies in the U.S. have engineering degrees. Is that many or is that few? Only 8 percent of all college graduates are engineers, so therefore I claim the percentage of engineers among CEO's is large. Now it is true that those people who have engineering degrees may also have MBA degrees. They also may have law degrees, and frequently do. If you plan to become the CEO of a major corporation, somewhere along the line after your engineering degree you may pick up a law degree or an MBA. So engineers, in fact, are present in positions of Chief Executive Officer of Fortune 500 companies in disproportionate proportion to their presence in the general population of the university, but they may well have an advanced degree in another field as well.

What about Presidents? Which Presidents of the U.S. have been engineers? Herbert Hoover--a bad role model, perhaps, but nevertheless the one that everyone remembers, at least of my generation. Jimmy Carter--if one were to ask people to name engineers who became president, most would recall Jimmy Carter and Herbert Hoover. Anyone else? What about Dwight Eisenhower? Over the last several decades, after the accreditation of engineering programs became the norm, military academies decided that they were offering an engineering degree. So, if you are a graduate of one of the military academies you are most likely an engineer. Thus we could include Dwight Eisenhower and we could also include George Washington, who really was an engineer. But those are debating points perhaps, and you may say that we shouldn't count Jimmy Carter, either. Someone might recall Thomas Jefferson, who was a Renaissance man and virtually everything, including an engineer and scientist. Nevertheless, the real point is that we've had very few engineers or scientists as Presidents of the U.S., at least in the usual sense. You do remember, I'm sure, that at present we have as President an actor who is also a major in Economics from Eureka College, a small church-related liberal arts college in the state of Illinois. Richard Nixon is a lawyer and I haven't found out what his undergraduate degree was. Lyndon Johnson was a school teacher with a degree in education from Southwestern State Teachers College. John Kennedy had a degree in some aspect of social science from Harvard. So we haven't had many engineers or scientists as presidents of the U.S., a really poor showing there.

I would recall for you that there are other CEO's in the political area, governors of states, and we do a little better here. The current governor of North Carolina, James Martin, has a degree in chemistry, a Ph.D. from Princeton. He did his post doctorate at Duke, and was on the faculty of Davidson College for several years. His predecessor, Jim Hunt, is known as a lawyer, but his undergraduate degree is in engineering from North Carolina State University. John Sununu from New Hampshire has a Ph.D. in engineering from the Massachusetts Institute of Technology (MIT) and was the Associate Dean of Tufts before he went into politics in New Hampshire. At the level of governor we do a little better, particularly in recent times.

Nevertheless, the question that was raised by Dr. Clark is still clearly stated; in which professions can the members count to their advantage the effort to make the good fight, run the good race for public office, and are defeated? Lawyers gain by virtue of running for public office, even if they lose the race. Engineers and scientists, on the other hand, would distinctly lose if they were defeated in the race for office. Therefore, entering politics is a high risk move for an engineer or scientist. Given the fact that there's one thing that many young people crave, namely security, it is not surprising to me that young people who have engineering or science backgrounds do not choose by and large to run for public office.

Perhaps it isn't surprising that Jim Martin and John Sununu came from the security of tenured faculty positions at Davidson and Tufts and moved from there, probably on a leave of absence, to serve in Washington or Raleigh or wherever. So maybe the message is we should encourage our engineering and science faculty to run for public office. We have a case locally, David Price. Mr. Price is currently on leave from Duke University, is a professor of political science, or of public policy, and is serving as our congressman. Clearly it isn't a bad thing to do to enhance your credentials professionally. My conclusion with respect to whole issue of why we don't have more leaders in the public sector who have backgrounds in engineering and sciences is that we shouldn't realistically expect people to run for public office when the career risk is so high.

Let me now turn to a couple of other points that Dr. Clark raised. Career selection: young people today, I would suggest, are largely selecting careers based as a desire status, money, and security. We can wish it were otherwise, but that's the way it is. A young person who has all of those already may opt for other values, but if in their perception they don't have a sufficient amount, then their college major selection and their career path selection will be greatly influenced by the perceived deficiency in one or more of those areas.

Dr. Clark suggested that talented executives tested better at a later age. That clearly would be true if you were testing them with respect to economics, accounting, or world history; I don't think it would be true with respect to differential equations. So I think that Dr. Clark's statement has to be tempered by the fact that the tests were not likely to assess areas of science and mathematics, at least not in great depth.

With respect to self-selection of leaders, I think although many people would enjoy the prerogatives of being a leader, there are relatively few who would care to have the responsibilities. When you are a leader, you are much more conscious, I would suggest, of the responsibilities than you are of the prerogatives. I would also suggest to you that to the extent that leaders are not self-selected, but selected by others, the quality of those leaders is greatly influenced by the quality of the followers. I think the quality of our Senators and Congressmen and even Presidents over the last several years is, if anything, above the general quality of the people who voted for them. So I don't think we have any real cause to complain.

Dr. Clark mentioned some statistics about dollars being spent by the universities versus dollars being spent by corporations on education of their employees. It's true that corporations are spending more money on the education of their employees than is being spent in universities in this country, which may seem surprising at first. However, there are about a hundred million people employed in this country and there are about four million people in our universities. Therefore it's not altogether surprising that we're spending more money on the education of a 100 million people than we are on the education of 4 million people.

Liberal education and its rationale. Liberal education, as we know it in this country, is largely vocational education as it was originally defined for the British ruling class about a century ago. A liberal education is often put forth as the choice of the person who isn't interested in grubby things like money, and careerism, and all those other nasty things that some people are interested in. In fact, liberal education was very much career oriented when it was established.

Graduate education and the selection of degree path, MBA, Ph.D, JD, MD, and all the rest of it. As Dr. Clark pointed out we have a very interesting paradox, although it is not really a paradox once you think about it. How many people know what an engineering or science graduate student is paid to be a graduate student at Duke, or Johns Hopkins, or Princeton, or Stanford? About $12,000 plus free tuition. Now that's not much compared to the $30,000 they could make if they had a job. Thus some allege the reason they don't pursue graduate programs is because of the difference between the $12,000 and the $30,000. On the other hand, $12,000 when combined with the $10,000 for tuition the $22,000 is a lot more than the law student, the business student, or the medical student is getting.

Consider the engineering or science student who has the choice between going to graduate school versus going on for an MBA for example. For the two years s/he would be in the MBA program rather than a graduate program, s/he would be in the red to the tune of a differential of $22,000 per year. Yet students are doing that in considerable numbers. Why? Dr. Clark suggests that they expect to make it up later on. Whether they do or not remains to be seen. But I agree that's the expectation and that's the reason for their decision.

Those are my comments on the issues raised by Dr. Clark. Maybe I've said something provocative that someone else will wish to challenge, correct or comment upon.

Discussant Reaction:
The Importance of Developing Leadership Potential of Youth With Talent in Science and Mathematics

Edward. G. Sherburne, Jr.

I found Dr. Clark's comments very suggestive, particularly some of his assumptions about leaders. I want to talk about them later on, but before I do, I think that I should explain a bit about my perceptions of talent, as I am neither an academic nor a psychologist.

Science Service, the organization for which I work, is a nonprofit agency whose largest activity is the publication of *Science News*, a weekly with a 200,000 circulation. Half of our subscribers are scientists and engineers who read the magazine for news out of their own field of specialty, and the others are "interested laymen."

Science Service has three other programs, all of which are at the precollege level. The Westinghouse Science Talent Search is a scholarship program which selects the winners on the basis of the quality of an independent research project in science, engineering or mathematics, with only secondary emphasis on academic achievement. The International Science and Engineering Fair is the "world series" of science fairs, and is much larger in terms of participation. The common thread between the two programs is that students are judged on the basis of a research project. The third program is the Directory of Student Science Training Programs for High Ability Precollege Students. This lists programs that provide course opportunities (like TIP) or research opportunities. The current 1988 Directory lists 507 programs, mostly sponsored by colleges and universities.

As a result of the kinds of precollege programs that we have, we look at talent in a rather different way from most of you. Essentially, we define talent in terms of scientific performance ("doing" science) rather than academic performance (grades and test scores).

To give you an idea of the kinds of students we are involved with in our programs, I want to read from a letter written by a scientist mentor of one of our students. In our two competitions, we have an increasing number of students who have done their research in a scientist's laboratory. So we ask the scientists to answer some questions about the students, and use these answers to help in evaluation.

Here are the replies to three questions:

1. Question: How did the student get the idea for the research?

Answer: He sought my assistance to carry out research in plasma physics in general and in double layers in particular. He explained to me that he became interested in this subject after reading several journals and one magazine article. Although the general focus of the research was entirely his, the actual experiment was decided upon jointly after several months of literature research.

2. Question: How independently did he work?

Answer: He worked very independently. He built experimental components, operated high vacuum equipment, assembled and maintained electronic diagnostic equipment, planned and executed all aspects of experimentation procedure, and individually analyzed all data.

3. Question: What did the student do to show creativity and ingenuity?

Answer: He formulated and attacked a completely new problem in plasma equilibrium of magnetized plasma. He was able to conceptualize the role of magnetic fields and their influence on equilibrium plasma and test several hypotheses as characterized in an entirely new experimental configuration which demonstrated a clearly measurable relationship between magnetic and density topology, and postulated the physical principle that may be responsible for this relationship.

This student was a twelfth grader, and probably did some of the research before the twelfth grade. So you can see that we are dealing with a kind of person who is something more than your high academic achiever.

I would like to support this anecdotal evidence by a study of the Honorable Mentions of the Westinghouse Science Talent Search[1]. As I have already indicated, the STS is a scholarship program that makes the selections on the basis of the quality of an independent research project in science, engineering or mathematics, with secondary emphasis on academic achievement.

In short, the evaluation is on the basis of the student's ability to use the knowledge possessed to "do" science in a way that is analogous, though not at such a sophisticated level, to what a professional scientist does. To use a sports analogy, one does not test a student's ability to play tennis by giving a paper and pencil test. One puts the student on the tennis court to play so that performance can be judged.

The study looked at three hundred Honorable Mentions in the STS a number of years ago. These Honorable Mentions were selected as usual on the basis of their research papers, that is, scientific performance. These three hundred were compared with three hundred selected from the total pool of entries on the basis of academic achievement as indicated by a weighted score from grades, rank in class, etc.

The two groups were compared to see how many students were in both groups. The results: only one-third of the students chosen on the basis of scientific achievement were also chosen on the basis of academic achievement. Conversely, only one-third of the students chosen on the basis of academic achievement had high enough scientific performance ratings to be chosen by that model. From this, I conclude that intelligent behavior in the classroom is not the same as intelligent behavior in the laboratory.

How can this be? If one looks at the laboratory--"doing science"--as opposed to doing classroom work, one sees some major differences. In a research project, you have long closure instead of the short closure typical of most academic work. You have real problems in a research project instead of the contrived problems of the classroom. You have complex problems in a research project, far more complex than any kind of problem that you can have in an examination. You have a whole different attitude toward failure and success. You can't fail in the classroom. In science you're very good if you ever succeed the first time around.

Thus, one can see that students who are successful in one context may not be as successful in the other. This has profound implications in regard to the future supply of scientists and engineers, a topic which is one of the principal concerns of this meeting.

A recent report by the Government-University-Industry Roundtable[2] states that the nation will soon face "a potentially serious problem in quality and quantity of technical personnel" unless more students are recruited into science and engineering. The group found that the number of twenty-two year-olds is expected to drop by more than twenty-five percent by the end of the century, with corresponding decreases in science and engineering students. To simply keep up with the 1985 level of twenty-two year-olds earning science and engineering baccalaureates, "the degree award rate would have to increase by thirty percent in the 1990's," the report says.

The situation would be relatively simple were it not for the fact that future scientists and engineers are recruited from essentially the same pool of high academic achievers as are in such fields as medicine and law. As the size of the age cohorts go down, the competition for majors in various disciplines can only be expected to become greater. And if we add future leaders to the groups to be recruited to the pool, the situation becomes even worse.

The first way to improve the supply is to increase the size of the talent pool as usually defined--high academic achievers. At the present time, it is largely made up of white males. It is always possible, of course, to upgrade their achievement level to make the pool larger, but the great potential for increase is among girls and minorities. This possibility is increasingly recognized, and a considerable amount of effort is being directed toward implementing it.

A second possibility is to increase the productivity of scientists and engineers. At the present time, all scientists and engineers are usually treated as though they were equally productive. This is by no means the case. In science, for example, between ten percent and fifteen percent of all scientists produce roughly fifty percent of the literature[3]. If the number of highly productive scientists could be increased, the research productivity would be increased far beyond their proportion to the total number of scientists. I cannot make any suggestions as to how to do this, but I do feel that productivity should be considered as well as numbers.

But neither of these possible solutions seem to me to take into account what I see to be a basic problem. What worries me is that the pool from which future professionals will be drawn is one whose sole criterion is academic achievement. The implication here is that intelligent behavior can be defined in terms of intelligent classroom behavior, and that intelligent classroom behavior is considered to be the same as intelligent scientific, engineering, medical, legal, business, industrial, military, etc., behavior. And it is considered to be the same thing as the behavior of the leaders in the occupations such as the ones I have mentioned. This is something with which I strongly disagree.

I refer to the study of the Honorable Mentions in the Science Talent Search, where the scientific achievers and the academic achievers were substantially different students. This is not to imply that academic achievement is unimportant. Mansfield and Busse[4] comment on the "threshold effect" that has been suggested by some psychologists. This suggests that there is a threshold academic ability level required for a discipline, but that beyond this level, additional academic achievement is not as important as the possession of such characteristics as creativity or motivation. In a sense, one could say that scientific performance guarantees the possession of the necessary academic achievement, as scientific research cannot be done without scientific knowledge. But on the other hand, it does not matter how much you know if you don't use it effectively.

The characteristics that help a person in one occupation are not necessarily the same for all occupations, and are not necessarily possessed in the same amount in occupations where they are the same. Robert Sternberg, in his "Beyond IQ"[5], talks about the context of intelligent behavior, and that "intelligence cannot be completely understood outside a sociocultural context and may in fact be different for a given individual from one culture to another." And he goes on to talk about "the weights, or importance, of the various aspects of mental hardware and software as they apply to defining intelligent behavior." In other words, intelligent behavior for the scientist in the laboratory is not the same thing as intelligent behavior for the leader in politics or business. And yet we are using this criterion as the principal means of identifying potential scientists, leaders, lawyers, politicians, etc.

I was talking about this to Betty Vetter, of the Commission on Professionals in Science and Technology[6], and she remarked that "the problem is that we do not know how to recognize talent potential, and so we use all kinds of substitutes such as grades and test scores."

I am especially concerned about all this in regard to leaders. In "Genius, Creativity and Leadership," Dean Keith Simonton[7] describes a study he did of the relationship between formal education and achieved eminence of leaders. He reports that "for leaders, fame is strictly a linear and negative function of formal education level. The highest ranked politicians, generals, admirals, reformers, diplomats, revolutionaries, and religious innovators have the least formal education. Evidently, higher education does not contribute to leadership potential." As he went back in history quite a way, one can speculate that this does not apply now. But it is very suggestive.

Why might this be so? I would contend that it is because there are characteristics other than those needed for achievement in formal education that affect success. For example, leaders tend to have charisma--the power or personal quality that gives an individual influence or authority over large numbers of people. We certainly don't know how to teach charisma, we don't know how to test for it, and we probably don't even know whether it is innate or learned. But our lack of knowledge about it does not mean that we should ignore it.

There are many other characteristics that contribute to adult occupational success that tend to be ignored as well. Perhaps the most important is motivation. To quote Sternberg again, he says that "differences in motivation may account for large shares of differences in observed performance, regardless of the level of the performance."

The point of all of this is that I think that the use of academic achievement to identify talent is too restrictive. I think that we have to include a whole host of other characteristics, which at least beyond the threshold level, are really what bring about adult occupational success.

In the terminology of Thomas Kuhn in *The Structure of Scientific Revolutions*, the paradigm has to change[8]. We have to move beyond seeing talent only in terms of intelligent behavior in the classroom, removed from any sort of relationship to real-world experience. It is twenty-two years since Donald Hoyt[9] published his classic review of forty-six studies on the relation of academic achievement and adult occupational success. In it, he concluded that despite the limitation of these studies, we can safely conclude from them that college grades have no more than a very modest correlation with adult success, no matter how defined.

I hope that we don't have to wait twenty-two years more before we do something.

Recommendations

The recommendations that I will present are made with a bias that probably sets me apart from most of the participants in this meeting. So before I go ahead, I should like to describe very briefly what these biases are:

- Intelligent behavior in the classroom is not the same as intelligent behavior in the laboratory, or to put it more broadly, as intelligent behavior in an adult occupation.

- Academic achievement does not predict adult occupational success.

- Various occupations have academic threshold levels which largely determine entry, but academic achievement beyond these levels does not contribute to adult occupational success.

- Personality attributes and other variables strongly affect adult occupational success once the threshold level of academic achievement has been reached, and it is these variables which account for different productivity levels of scientists.

I should like to make the following recommendations:

1. The database being considered should be called something like the National Database on Adult Success in Mathematics, Science and Technology, rather than the National Database for the Academically Talented in Mathematics, Science and Technology.

2. The academic information contained in the database should be related to at least the upper 15 percent of precollege students and not restricted to the 3 percent or whatever level is used to designate gifted and talented.

3. The database should include non-academic data, that is, data on the multitude of other variables that contribute to adult occupational success. This might include:

    a. Personality attributes: creativity, persistence, independence, initiative, etc.

    b. Motivation.

    c. "The significant others"--teachers, mentors, peers. This should include information on role models.

    d. Family. Our experience with the Science Talent Search Asian winners strongly suggest that family can be a major variable in achievement.

    e. Precollege extracurricular experiences, especially contests. These include the Science Talent Search, the International Science and Engineering Fair, the International Olympiads (mathematics, physics, chemistry), etc.

    f. Identification of successful scientists so that retrospective studies can be done on their life history. A classic example "Developing Talent in Young People," Benjamin S. Bloom, editor, Ballantine Books, 1985.

    g. Follow-up to give career choice of individuals and their eventual occupation.

    h. Record of achievements: awards, membership in the National Academy of Science, etc.

    i. Some tie-in with the Citation Index as a means of showing adult success and particularly, research productivity.

    j. A collection of the data from other studies (not just the studies themselves), so that this data can be reused. This is done in public opinion research, and while I assume that it might be more difficult in this instance, I feel that it should be considered.

Notes

1. Edgerton, H. (1973). Identifying high school seniors talented in science. Science Service, Washington, DC. Mimeo.
2. Nurturing Scientific and Engineering Talent. (1987). Government-University-Industry Roundtable. National Academy of Sciences.
3. Cole, J. (1987). Women in science. In D. G. Jackson and J. P. Rushton (Eds.), *Scientific Excellence*. Sage Publications.
4. Mansfield, R. and Busse, T. (1981). *The psychology of creativity and discovery*. Nelson-Hall.
5. Sternberg, R. (1985). *Beyond IQ: A triarchic theory of human intelligence.* Cambridge, Massachusetts: Cambridge University Press.
6. Vetter, B. Executive Director, Commission on Professionals in Science and Technology. Personal Communication.
7. Simonton, D. (1984). *Genius, creativity, and leadership*. Harvard University Press.
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PURCHASE AND POSSESSION: A NATIONAL DATABASE FOR THE SCIENTIFICALLY, MATHEMATICALLY AND TECHNOLOGICALLY TALENTED

Robert N. Sawyer

In 1803, a mixture of good fortune, national security issues, foreign entanglements, and American interest in frontier expansion conspired to bring about the Louisiana Purchase, which (as we know from our second grade teachers) doubled the national domain. The territory had excited President Thomas Jefferson's imagination for at least the twenty years before he pushed for the purchase–and then not merely on imperialist grounds, though of course such considerations also came into play. Jefferson thought at one point that prehistoric mammoths might still be alive somewhere in the reaches, and he had heard that its wilderness contained a mountain of pure salt. In 1803 the ink had dried on an agreement–$15 million for a largely mysterious chunk of North American real estate. To dispel some of the mystery, on June 20, 1803, President Jefferson charged Meriwether Lewis "to explore the Missouri river, & such principal stream of it, as, by it's course & communication with the waters of the Pacific Ocean, may offer the most direct & practicable water communication across this continent, for the purposes of commerce." Jefferson's charge reflects a continental vision.

Surveying longitude and latitude were primary interests in this expedition, but Jefferson also included strategic objectives: "The commerce which may be carried on with the people inhabiting the line you will pursue, renders a kno[w]ledge of these people important," Jefferson wrote, giving Lewis the task of scouting out the native customs, lands, possessions, language, monuments, various "ordinary occupations," and "moral & physical circumstances which distinguish them from the tribes we know." –In short, the President required intelligence for businessmen, armies, and diplomats. And yet, Jefferson was also himself a naturalist and America's "Renaissance man," as his keen interests in "philosophical" (by which he denoted what we term "scientific") pursuits of the voyage reveal: "Other object worthy of notice will be the soil & face of the country, it's growth & vegetable productions; especially those not of the U. S. the animals of the country generally, & especially those not known in the U. S. the remains and accounts of any which may deemed rare or extinct; the mineral productions of every kind [. . .] Volcanic appearances. climate as characterized by the thermometer, by the proportion of rainy, cloudy & clear days, by lightning, hail, snow, ice, by the access & recess of frost. . . ."

The Lewis and Clark Expedition has its authentic historical worth not because it marked the first footsteps of white men upon the inner ground of the American continent, but because of the information it brought back to the "familiar" lands of the Eastern seaboard. Meriwether Lewis and William Clark were not the first to make a transcontinental voyage–Alexander MacKenzie had preceded them in fact–but their voyage was documented and "philosophically" authoritative.
In the Lewis and Clark Expedition, the territorial fact of the Louisiana Purchase is transformed into an American natural resource. The expedition itself was the act of possession; the possession itself was the knowledge.

The author is deeply indebted to Dr. Mark R. DeLong, Research Associate, for his invaluable assistance with this paper.

The differences between the Jeffersonian America and today's America are obvious. Long ago we reached the western shores, and we have already experienced the implications of our "Manifest Destiny." We know the blessings of the natural riches of Jefferson's Louisiana Purchase. But where Jefferson's America faced a physical wilderness, we today face a wilderness of economic and technological challenges. Our challenges are no less daunting, though they apparently draw less on military cunning, Indian diplomacy, and physical endurance. We now confront an age when our national expansion will be articulated in more rarified terms–in the vocabularies of knowledge, technical ability, and inventiveness. It may even be the case that such scientific and technical abilities will press man beyond the geography of this world and on to a newer and more spacious frontier–the heavens. America at the beginning of the nineteenth century had advantages that no other nation had in the recorded history of man–it had an open backyard with natural riches. But America has stepped into the situation of every other modern society. Now, we are faced with the dilemmas and the physical restrictions of the so-called "Old World," and our society has matured from its "New World" infancy. As John Gardner wrote, "The demand for talent is an inevitable consequence of our stage of development as a society. . . . It is not a new trend. We can observe societies in the world today at every stage of development from the most primitive to the most advanced, and nothing is easier to demonstrate that every step toward the latter involves a heavier demand for educated talent" (Gardner, 1961, p. 36). In a sense, Lewis and Clark had it easy, for their challenge had a certain deadly simplicity in the meeting of an infant America and the unformed wilderness of the Louisiana Purchase.

The relationship of a nineteenth-century expedition and a twentieth-century social research task may be a bit fuzzy. I do, indeed, wish to talk about the place, framework, and importance of establishing a national database which could be vital to the current and longitudinal knowledge of academic talent in mathematics, science, and technology; but I also think it would be an abuse of the spirit of this conference merely to focus on the specific details of such a database, as if the techniques of data collection were self-justifying. And so, I think it is important to approach that research task with an informing vision--a vision, I believe, which arises from the peculiar history of the Louisiana Purchase, which is virtually the history of an American continent. We have tended to justify our research in scientific, mathematical, and technological talent with the rhetoric of invasion and desperation--through our work we seek to dam a "rising tide of mediocrity" or keep our children from becoming "stragglers in a world of technology" or work to prevent the extinction of an American "industrial dinosaur." I think that it is time to transform our rationales from the reactive toward the active, to turn from extinction and desperation toward opportunity and enriching challenges. Our nation has "signed the agreement," so to speak, for a Louisiana Purchase of human talent by centering its attention in a significant way on the educational preparation of its children; and, in a sense, the fact that this Talent Identification Program/National Science Foundation conference has come to pass is evidence of that "agreement." However, the claiming of human talent and human resources comes with what goes on after the "agreements" are signed--when we send our own Lewises and Clarkes into the newly purchased wilderness to scout out what riches, what opportunities, and what perils are held within it.

Our twentieth-century Louisiana Purchase is our commitment to educate for future prosperity; our expeditions into that raw opportunity will inform us and allow us to "take possession" of the human resources of our nation. John Curtis Gowan used a related (though violent) wilderness metaphor when he said to those attending the Seventh Annual Hyman Blumberg Symposium on Research in Early Childhood Education: "Heretofore we have harvested creativity wild. We have used as creative only those persons who stubbornly remained creative despite all efforts of the family, religion, education, and politics to grind it out of them, in prosecution of which men and women have been punished, flogged, silenced, imprisoned, tortured, ostracized, and killed. . . . As a result of these misguided efforts, our society produces only a small percentage of its potential of creative individuals, and they are the ones with the most uncooperative dispositions. If we learn to domesticate creativity–that is, to enhance rather than deny it in our culture–we can increase the number of creative persons in our midst severalfold" (1977, p. 22). Gowan's militance and passion are apparent and, perhaps, a bit affronting, but the point is made. If we wish to prosper, we must possess the wilderness and purposefully derive from it what we have up to now only haphazardly found in our midst. To do that we need to know what's there, and we need to determine the factual basis of the stories of mountains of salt or living mammoths in the midst of the wilderness. We need to answer questions and dispel myths.

The need for national research on the topic of academic talent came especially clear to me in 1983, when the Children's Caucus Policy Forum of the United States Senate invited five TIP youngsters and me to tell them about ourselves and what we do and need. My colleague Greg Kimble was my proxy as it finally turned out, since I was trapped in an airplane on a foggy runway in Philadelphia. Later, my good friend Bill Bevan said to me that anyone who knows anything takes the train from Philly to Washington. How was a farm boy to know? The Senators had a number of questions –which of course Professor Kimble and the students ably fielded. After the fog cleared in Philadelphia and I arrive for only the final moments of the testimony, Professor Kimble and I later talked in sunny Durham about the testimony and the questions, only to find out that our safest and most informed responses had meaning largely within the sixteen-state region TIP serves. That point is, indeed, unsurprising; but its implication still is foreboding: *Our knowledge of academic talent is limited not only by the scarcity of research funds but also by the very institutional focuses of the universities doing the research.* There is no single and reliable place where information on our nation's talent can be procured. And even when information is teased out of the variety of researchers, the resulting picture is a crazy quilt of information, informed by different methodologies and shaped by different research assumptions. Variety is rich, but the information necessary for sound national public policy on the development of academic talent sorely lacks.

To use Jefferson's delusion as an analogy: We can still easily believe that mammoths still survive in the wilderness of talent. But what if policies were to be shaped around their existence?

Initial Explorations: The Terman Studies

In 1921, Lewis M. Terman initiated the prototype longitudinal study of the gifted, and his data has been a very rich source of information over most of the century. He began by identifying 1528 students aged 8 years and older with IQs of 130 or greater and creating a database incorporating numerous variables. The group initially completed inventories on their academic and social activities and a test of moral character. Parents provided information on the home environment, and teachers reported on the physical, academic and social life of the child at school by drawing on observation and school records. This compilation of different kinds and sources of data has increased our understanding of many of the relevant features of academic precocity, its psychological vulnerabilities and resilience, and the life and career acheivements of those blessed with an intellectual gift. Societal changes, methodological advances, and even the knowledge derived from these studies themselves have rendered the data from the original study in some ways incomplete. Terman's study raised many questions which the data could not respond to.

Terman and his colleague Melita H. Oden believed that the selection of subjects for the study ensured "that the group selected for study constituted a reasonably unbiased sampling and that whatever traits were typical of these children would be reasonably typical of gifted children in an comparable school population" (Terman and Oden, 1959, p. 53). The "comparable school population" chiefly fit "the public schools of the larger and medium sized urban areas of California (Oden, 1968, p. 5). It is worth bearing in mind that the initial identification instrument was the 1916 Stanford-Binet Intelligence Test (largely a revision done by Terman himself), followed by the Terman Group Test of Mental Ability, which provided the norms to make sure that participants scored in the top 1% of the general school population. With our healthy suspicion of the implications of intelligence testing, we might suspect that aspects of the Terman study are as much about the 1916 Stanford-Binet and the Terman Group Test of Mental Ability as they are about the 1528 subjects who were studied.

Follow-up contacts in the Terman study were conducted at an average of five-year intervals, alternating between field contacts and by-mail contacts. Terman's field contacts occurred in 1927-28, 1939-40, and 1950-52; by mail contacts occurred in 1936, 1945, 1955, and 1960. Robert Sears and Lee Cronbach did another followup survey in 1972. Subsequent study has also been conducted on the Terman group, who are otherwise known as "Termites," by Robert Sears, Pauline Sears, Ann Barbee, Lee Cronbach and others. The study was well maintained. Oden wrote in 1968 that the "extent to which contact with the subjects has been maintained is unequalled for longitudinal studies. In the course of the investigation only 26 subjects (10 men and 16 women) have been lost track of entirely" (Oden, 1968, p. 6). In the field studies, about 95 percent of the subjects participated.

The Terman study is to be praised for its rich basis and careful administrative preservation, but the study has its boundaries, as do all human endeavors. And in its shortcomings lie the most vexing and pressing issues of today's research into the academically talented. One of the things that Terman did not do is precisely what most of us in this room wish to do--intervene at some point in order to foster talent, to guide and enhance the resources of our talented citizenry. Terman's passivity in this regard could have come from his early conviction that talent (his term is "giftedness") is an unalterable hereditary attribute. He found that the "Termites" maintained their intellectual advantage through the course of the study, as determined by Concept Mastery tests administered as part of the field studies. The characteristically descriptive tone of the literature produced from the Terman studies falls out of that belief, for

Terman's idea of "causality" in the acquisition of talent was prefabricated, so to speak, by the fact of nature. Terman and his associates likely felt that the causes of success were so apparent in the descriptions of "giftedness" and the fact of IQ scores that they needed little other speculative or theoretical basis. It is no coincidence that his work, and that of his successors, appeared in a series called *Genetic Studies of Genius*–a series, incidentally, that Terman founded at Stanford. Terman recognized his kinship with Francis Galton, even though he felt a greater personal tie to Alfred Binet for his "insight and openmindedness, and his rare charm of personality" (Boring, 1959, p. 331).

Nevertheless, simply to brand Terman a genetic determinist is also to misapply a label. Certainly, in 1932 he wrote: "That the major differences between children of high and low IQ, and the major differences in the intelligence test scores of certain races, as Negroes and whites, will never be fully accounted for on the environmental hypothesis" (Terman, 1932, pp. 329-330). Those are the words of a determinist, and we would probably also include the label "racist" as well. But these words from 1932 were reconsidered in 1951, though regrettably not in public form. Terman's own copy of the book in which the words appeared (his autobiography) strikes this sentence and includes the marginal comment: "I am less sure of this now in 1951 than I was then." The certainty of genetic inheritance evidentally waned over those interceding twenty years.

Early prejudices and hunces did set the mold for the Terman longitudinal study. Socioeconomic status factors (which Terman would probably have set within the bounds of the "environmental hypothesis") were not controlled in the study, and the study did little to investigate or control ethnicity. These two holes in the Terman study are probably among the most interesting for researchers in academic talent today, and yet in response to these problems today's researchers have conducted miniscule longitudinal studies in comparison with the efforts Terman and his colleagues mounted. Money, quite frankly, is a major impediment today, as it was in Terman's day as well. Terman did have test royalties, though, and those resources provided for more than a half of the approximately $250,000 it took to do his study. I know of only a few researchers today who would invest so much of their own money into a project, and I know of no plans for any major longitudinal study that would require only a quarter million dollars to conduct.

Virgil Ward said that "we should constantly remind ourselves that Terman himself spoke of his research as being a 'prolegomenon' to education; and that science is advanced by alternating transactions between controlled investigation and reflective imagination" (Getzels, 1977, p. 258). A new and ambitious longitudinal study of academic talent should follow that spirit. Although Terman did not initiate much beyond his "prolegomenon," our contemporary efforts should have in mind the implications of, and practices deriving from, basic knowledge. Especially in education, we have a social and also a scientific agenda. We seek to know so that we can educate; we educate so that we can empower; we empower so that we may live justly. Our emerging longitudinal studies of all facets of academic talent must squarely face what Terman skirted: the centrality of socioeconomic factors and the "environmental hypothesis" that comes into play when the facts of nature meet the concrete realities of everyday life.

The Equipment of Today's Expedition: Regional Talent Searches

Records show that Lewis and Clark equipped themselves with what must have been a mountain of sundry articles, including, oddly enough, a heap of pewter spectacles, and a gross of shower curtain rings–provided, we are told, as ornaments for Indian ears, fingers, and noses. Lewis was particularly pleased by an iron boat frame, light-weight enough for ease of transport and collapsable at that. All you add is a birch-bark sheath. With these supplies, the party left St. Louis to wander and observe, scouting out what a wilderness had as resources.

The analogy I have set up between a national and perhaps longitudinal database and that nineteenth-century expedition, without a doubt, borders on the "metaphysical." But, at the risk of no little humor, I wish to exchange equipment, as it were, with Lewis and Clark. We have already at our disposal the guidance of Terman and his successors (a scientific group acting as our Sacajawea), and we have a group of loosely coordinated and cooperating regional talent searches located at Duke University (Talent Identification Program–TIP), The Johns Hopkins University (Center for the Advancement of Academically Talented Youth–CTY), the University of Denver (Rocky Mountain Talent Search–RMTS), and Northwestern University (Midwest Talent Search–MTS). Incidentally, the directors of these regional searches are all attending this conference. The organizations at these universities have taken responsibility for conducting annual talent searches using the same basic model which was developed by Julian C. Stanley at The Johns Hopkins University, though the search process varies greatly in size and details. The searches cover the entire United States in geographical regions agreed to by each organization. Basic information collected by the searches is matched with additional information requested from applicants, so at the completion of each search year, a basic profile of talent search applicants is available for the "instant" of their middle school years.

Each of you attending this meeting likely as not already understands the form of the talent search process, and so I will not dwell too long on its particularities. In brief, the talent searches invite seventh-grade students scoring in the upperthree percent on a nationally-normed achievement or intelligence test to apply. These applicants sit for the Scholastic Aptitude Test (SAT) or, beginning this past year through the Talent Identification Program, the American College Testing Program's ACT Assessment. The experience of the search organizations over the years has shown that the out-of-level SAT provides meaningful measures for academically talented students and is a reliable predictor of success in high-level and fast-paced academic programs specifically designed for extremely talented youth. Research conducted so far on the ACT suggests that it is not greatly unlike the SAT in those respects. The participants in the talent searches in general perform nearly as well as college-bound high school seniors, and many out-perform their older fellow test takers. Many have scored in the upper 700s on the SAT-M and SAT-V, and a handful have scored "perfect" 800s on the SAT-M. Many students have performed at the upper end of the ACT score spectrum. The group of students has at the outset a more specific profile than Terman's 1,528 individuals had, for although the Stanford-Binet which Terman used was perhaps then the best single instrument for determing intellect, it is nonetheless a *global* composite. The SAT and, we believe, the ACT provide more specific information about intellectual ability in more specific domains, making it easier from the outset to estimate aptitude by area of knowledge (See Stanley, 1977).

The extant electronic databases at TIP and CTY alone have an estimated combined size of about 400 million bits of information, with each program collecting an additional 20 million bits of information yearly (about 8,000 typed manuscript pages). The data collected by the Denver, Duke, Johns Hopkins, and Northwestern programs comprise a common base of information, but despite the common elements, differences in wording and emphasis exist. This fact makes simply merging the existing databases difficult and, in some areas of interest, impossible. The databases contain attitudinal, demographic, achievement, and motivational information on students, as well as information on characterisitics of their families and schools. Most importantly, the vehicle for annually collecting common data from more than 110,000 students in all fifty states currently exists.

More specifically, the databases contain the following basic information:

- *Student identification information* including name, address, and telephone number as well as the name, address, and telephone number of another relative who is likely to know the future whereabouts of the respondent;
- *Family composition* including the number and age of parents, siblings, and the presence of twins;
- R*espondent's grade and age;*
- *Parent's education, job status, and job title;*
- *Ethnicity;*
- *Academic attitudes* including like or dislike of school in general and of specific subject matter, such as science and mathematics;
- *Method of learning, background in, and acceleration* in mathematics, science, humanities, social studies, and languages;
- Participation in *individual and group learning activities,* science fairs, and gifted programs;
- Preferences regarding *college major;*
- Preferences regarding which *college to attend;*
- *Occupational preferences;*
- *Means of becoming aware of the respective talent searches;*
- *Interest in science, mathematics* and a variety of other academic offerings;
- *Age-normed performance scores* as measured on one or more nationally standardized test(s) [see note 7];

- *Out-of-level/age performance "achievement" scores* as measured by the Scholastic Aptitude Test or the ACT Assessment; and,

- For the many respondents having taken the SAT on multiple occasions, *multiple scores and the date of test administration.*

In addition to the basic annual data collections, TIP, CTY, MTS, and RMTS have each conducted special purpose surveys and research efforts in select subpopulations derived from the programs' individual talent search pools. While the TIP efforts have focused on cross-sectional research issues, several studies have been of a longitudinal nature. The TIP studies are diverse, including such specific programmatic and basic research as:

- *Course performance measures for academic program participants* used, in part, to gauge teaching effectiveness. The battery of measurements of knowledge gain and mastery includes 1) pre- and post-measures on standardized or instructor designed exams, 2) pre-course diagnostic exams and post-course standardized tests, and 3) performance measures relative to other participants.

- *Measures, focusing on academic and social satisfaction with the program.* We have sought to identify potential mediators and motivations students have in the academic and social aspects of the academic programs, and we have used this information in evaluative studies as well as in prediction of academic performance in the summer residential program.

- *A longitudinal study* with five cohorts of academic program participants *designed to identify immediate and deferred outcomes of involvement in the educational programs.*

- *Standard measures of intelligence, perceived competence and early psychological and behavioral development* have been collected from cross-sections of three groups: 1) academic program participants, 2) equally qualified talent search participants who did not participate in academic programs, and 3) similarly aged youth from public schools. We conducted this research in order to investigate the nature and course of development of academic talent; and

- *Assorted personality measures* (e.g., CPI profiles) have been collected on select cross-sections of talented students and comparison students in order to identify personality traits which can help to distinguish the populations.

While data for these individual projects have been computerized, we have not completed tying the various TIP databases together to make them into the larger talent search database (though we hope that this will be accomplished by April, 1988). Lack of both time and financial resources has relegated these tasks to a relatively low priority. Up to now our research efforts have dealt with specific programmatic issues or have consisted of easily accomplished basic research.

The brief description of the database contents--in however many individual files--shows that the information already collected is substantial and could form a sound foundation for future basic and applied research. I suspect a similar statement could be made regarding the other talent searches. There are, however, improvements that can significantly increase the usefulness of the databases, some of which have been instituted at TIP. Since 1987, participants have provided their Social Security numbers to simplify the merging of data into the database. Incidentally, with the 1986 Tax Reform law, youngsters who are claimed as dependents must have Social Security numbers by their fifth year. Although in 1988 about 70 percent of TIP's talent search applicants supplied Social Security numbers (a fact which itself has some significant implications), we expect that nearly 100 percent will do so in future years. Three other significant additions were made in the annual questionnaire in 1987:

- We began to request additional demographic data about housing characteristics, including noise level in the home.
- We first included brief measures of personality characteristics, including self-concept, motivation, and adjustment items as they relate to academic and social activities.
- We started to collect information on environmental characteristics with a truncated age-appropriate life events scale and an inquiry about current and past health.

TIP's current questionnaire has developed from an initial questionnaire circulated in 1981. Although the present TIP questionnaire does cover similar points as this initial protocol, it has been considerably expanded and refined. We expect this process of revision to continue at TIP, as it will no doubt continue at the other regional searches. And for that reason, as with isolated populations of living things, evolutionary distinctions will arise among the data-gathering instruments of the individual talent searches, a fact which will probably make large-scale research collaboration increasingly difficult. A national database would not halt the evolutionary improvements in such research protocols as annual questionnaires, but it would coordinate and make such development methodical and self-conscious across the nation. And, indeed, a national program to supply the information to the database should *not* squelch the individual research agendas of each talent search organization. TIP's talent search region, for instance, has certain demographic characteristics that other searches do not have, and our organizational interests--including research--justifiably play on those distinguishing characteristics. Moreover, we all recognize that research staff members have their own peculiar research strengths and interests. A nationally dictated or overly centralized research agenda would make everyone play to same tune–and the harmonies of scholarship would probably wane. And, conversely, the absense of coordinated effort encourages redundancy and inhibits the kind of scholarly exchange that encourages individual accomplishment and insight. We need to find a mechanism that will optimize both the resources of basic information and the energies of those who will make sense of it.

The strength of talent search numbers and the research staffs would be strengthen by comprehensibility of research on its individuals. The numbers alone are formidable: this year TIP received about 46,000 applications, CTY nearly 36,000, the Midwest Talent Search 25,500 and the Rocky Mountian Search 4,500. A national database should supply a core of data for use in comparison and in founding general characteristics of talent, but it must in any case preserve the peculiar identities of the researchers who use its information. To use the expedition metaphor again: we could, with a correct measure of external guidance and data sharing, all be looking at a different portion of a wilderness with a mind to create a coherent map of its resources and characteristics. This map could then be used by all who chose to do so.

Ways and By-ways: Points of Governance and Coordination

To find the correct measure of guidance and sharing, we can probably best begin with what may appear to be details. We can most easily work together to determine 1) the variety, number, and length of assessment devices that can responsibly be administered, 2) a possible research agenda or even a series of possible agendas, even if only in a brief outline format, which could efficiently use the proposed database as a cornerstone, and 3) the feasibility of funding various stages of the project. There is little practical sense in development if there are no resources for implementation.

Of course, each of these three points actsupon one another. Topics of research will influence the development of core questionnaires. And certainly, special interest studies will in all likelihood guide both the instrumentation and timing of data collection. The talent search questionnaire as a genre, if I may use a literary term, has its own limitations and strengths which good research projects will inevitably use to their advantage. Several topics for investigation have already been suggested by Janos and Robinson (1985), among others, and by TIP, CTY, MTS, and RMTS talent search and research staffs.

Of particular interest is longitudinal research on nationally representative samples of mathematically/scientifically/technologically talented youth. Longitudinal research projects could study the nature and effects of mathematical and scientific talent across the entire life span. At present there is no such database and consequently no clear understanding of mathematical and scientific talent within a developmental context. Here, specific topics of interest might include:

- *Developmental pace, milestones and progress* of individuals identified as academically talented compared to competent individuals;

- The *relationship of intellective functioning, personality characteristics and social adaptation;*

- The *determinants of educational and vocational choice and success* among academically talented children. Here, the study of sex differences in choice and later success may be particularly importance;

- *Stress and development of coping strategies;*

- The *impact of select environmental and educational intervention strategies*.

Other options include studies of cognitive functioning, studies in the selection of careers in science, mathematics, and technology, studies of leadership, comparison of identification by means of SAT or ACT with other identification mechanisms, short-term evaluation of educational or social interventions, and studies of sex differences or racial and ethnic differences.

By establishing both a tentative research agenda and tailoring annual assessments to obtain as much of the necessary baseline data as is feasible, many research efforts could be completed quite quickly, and research on topics beyond the immediate scope of the general database will be able to use the resources nevertheless to localize and control groups to study.

It should be apparent by now that if a truly national database and a coordinated research agenda is to come into being at least a loose confederation of the four talent searches will need to come about. And, as I am a realist in matters of governance (heaven forbid!), I realize that in university communities the looser the confederation, the better. I will not discuss my thoughts on the make-up of such a governing body--the time of such a "constitution" has not yet come--but I will share my views on what seems most in need of governing.

Reporting system. A national database is little more than a collection of easily accessible information, distinguished from a card file in your basement or your tax record file only by dimension. As we all know from our tax filing forms (at least those of us who still have time and patience enough to figure them out ourselves), the more information, the greater difficulty is maintenance. At tax time, there are always a few undocumented receipts and notations which once made sense but do no longer. In a national database for mathematical, scientific, and technological talent, the problem is multiplied as each bit of electronic data is added. I know this from experience, for as our database grew to nearly 250,000 names over eight years, so also did nagging programming and formatting inconsistencies. What was in 1984 merely a "character" turned in 1985 into an "integer"; and, unfortunately, the two do not mix well in SAS. Procedures for adding and modifying data are the most basic and most pragmatic service of a governing body. It almost goes without saying that the group of cooperating organizations should standardize agreed upon "baseline" data assessments in their talent search questionnaires.

Location, staffing, and governance. Locating the "place" of the data should be carefully studied, though some location characteristics come immediately to mind. The area should be in close proximity to major research centers in education, science, and technology so that it could easily draw upon the expertise of the scientific and academic community. Facilities for optical scanning should be accessible and the area must already be considered a major computing center. Perhaps the database organization could be part of a constellation of activities drawn together under a larger "national center" for academic talent, conceived in terms of the education bill recently passed in both houses and now in conference committee in Washington. The database center will doubtlessly require significant space and full-time staff, including programmers, researchers, a project director, and numerous other professional staff. Governance for the overall organization should not be confined to the educational establishment or to those who claim to concentrate on "gifted education." Rather, a board of directors should comprise researchers, policy makers in both state and federal government, industry leaders, those with experience in the development and management of large databases, along with those of us charged with conducting the annual searches and collecting the data.

Mechanism for regulating use of data. Pragmatic considerations always imply ethical considerations, for what can be done may not always be what *ought* to be done. We collect data in trust, and it is absolutely essential that our use of that data accords with that trust. I believe that the best form of regulating uses of data is to structure inadequacies into it, allowing the masks and veils to be put aside after that which they cover is shown not only to be useful for the immediate topic of study but also necessary and within the moral bounds that are placed on it when we establish consent agreements. This data, for example, can be misused in admissions offices, government offices--local, state, and federal--and in offices of development; since it is placed into the hands of researchers for the sake of research, the data must remain within that scholarly frame of reference. Data must remain confidential and anonymous except to those in charge of maintaining the database.

I believe that a phased coordination of the talent searches would be most practical, beginning with the collaboration of TIP and one other regional search with an eye toward eventually including all regional searches. Perhaps TIP and CTY could start because their databases are probably most similar. Over a period of three to five years, these programs should be able to:

- *Link the development of talent search questionnaires* to bring about compatibilities of baseline data;
- *Establish a board of peers* to evaluate proposals seeking to use jointly maintained data, to set up guidelines for smooth coordination of data merging and entry, and to regulate access of data by stages according to the needs of bona fide researchers;
- *Provide timely national reports on database contents*, especially as it relates to science and mathematical talent, ethnicity, geographical region and community type, school type, and other factors of SES;
- Expand and *direct talent search questionnaires* to address research topics of national concern and to met specific needs of special collaborative research as it arises.

These points seem to me to be in roughly chronological order, though the rigor with which each item is put to use should also intensify over time. The primary aim, of course, is the acquisition of new and useful knowledge; the secondary (though closely related) aim is to intensify research collaboration.

* * *

I introduced this discussion with a wilderness metaphor, and it seems appropriate--if for no other reason than symmetry--that I close it with the wilderness. The words are Robert Frost's, and they are close to my heart:

> The woods are lovely, dark, and deep,
> But I have promises to keep,
> And miles to go before I sleep,
> And miles to go before I sleep.

We do, indeed, have promises to keep, and we have "miles to go" before we have entered the new purchase of creative human talent.

Notes

1. See the National Commission on Excellence in Education's 1983 report called *A Nation At Risk: The Imperative for Educational Reform* (Washington, D. C.: U. S Government Printing Office, 1983) and the National Science Board Commission of Precollege Education in Mathematics, Science and Technology's *Educating Americans for the 21st Century*, 2 vols. (Washington, D. C.: National Science Foundation, 1983). It is worth noting that the survivalist rhetoric has been around for some time. Sidney L. Pressey's "Concerning the Nature and Nurture of Genius," *Scientific Monthly* (1955) *81*: 123-129, opens with the comment, "It has been well said that 'in the present international tug of war, survival itself may depend upon making the most effective use of the nation's intellectual resources.' " Those words were of the pre-Sputnik era, and Pressey's use of the idea suggests that it had long been elevated to the level of common-sense truism–an old adage or bromide.

2. John Gardner also used the naturalist metaphor in *Excellence: Can We Be Equal and Excellent Too?* when he wrote: "Generally speaking, individuals whose gifts have been discovered and cultivated have been as chance outcroppings of precious rock, while the great reserves of human talent lay undiscovered below." Julian Stanley cites Thomas Gray's "Elegy Written in a Country Churchyard" (1751) which reads in part:

> Full many a gem of purest ray serene
> The dark unfathomed caves of ocean bear;
> Full many a flower is born to blush unseen,
> And waste its sweetness on the desert air.

The citation is, perhaps, unfortunate in that the obvious referent of the lines in the original poem is the group of "inhabitants" of a church graveyard. But, poetry out of context still can make a point, so long as we have fuzzy memories. Gardner cites what Thomas Jefferson said of his vision of the American educational system: "Geniuses will be raked from the rubbish." That metaphor, perhaps, is for another to employ, despite its color! Though the poetic and stylistic description of talent is itself interesting, I will now leave it to literary critics to explicate.

3. This descriptive tone has been attributed to Terman's own affable personality and administrative style (Gowan, 1977). Terman himself noted the tone of his researches, writing in his autobiography, "I am fully aware that my researches have not contributed very greatly to the theory of mental measurement" (Terman, 1932, p. 328).

4. Oden did report in 1968 that the most successful men of Terman's group came from families of high socioeconomic class, with higher levels of educational achievement, and a stable family structure. Moreover, the families of successful male "Termites" were more likely to support them financially and emotionally during years of academic and professional preparation.

5. Other significant longitudinal studies have been conducted by Julian C. Stanley and his colleagues at The John Hopkins University's Study of Mathematically Precocious Youth (SMPY), which was begun in 1971.

6. For instance, qualifying scores for applicants at the Rocky Mountain Talent Search are in the upper five percent (as opposed to the upper three percent) and, also at that search, students may be in the seventh or the eighth grade at the time they apply to the search. Duke's search was the first to use machine-readable application forms and to use computers throughout the operation–an innovation that has technically revolutionized the search concept. Now such forms are the rule rather than the exception, and machines have made extensive searches much more technically feasible than they were previously. Further, the Duke program has pioneered in using the ACT Assessment as an alternative means of identification.

7. Duke's Talent Identification Program accepts students who qualify on one of the following tests: Iowa Test of Basic Skills, California Achievement Test, Stanford Achievement Test, SRA Achievement Series, Comprehensive Test of Basic Skills, Metropolitan Acheivement Test, Test of Cognitive Skills, ERB Comprehensive Testing Program, Comprehensive Assessment Program Achievement Series, Cognitive Abilities Test, Kentucky Essential Skills Test, Wechsler Intelligence Scale for Children–Revised (WISC-R), Secondary School Admissions Test, Developing Cognitive Abilities Test, Kuhlmann-Anderson Test, National Tests of Basic Skills, Otis Lennon School Ability Test, Peabody Individual Achievement Test, School and College Ability Tests, Sequential Tests of Educational Progress, STS Educational Development Series (ED Series), 3-R's Test (Achievement Test, Ability Test), Wide Range Achievement Test–Revised (WRAT-R).

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Discussant Reaction: Purchase and Possession: A National Database for the Scientifically, Mathematically and Technologically Talented

Robert J. Thompson

A discussant's role is difficult in that it involves trying to amplify some of the presenter's points, in a relatively short period of time, without being superfluous. Although the task can be difficult I approach this one with considerable enthusiasm because of the importance of the question and the effectiveness of Dr. Sawyer's paper in eliciting commitment to this area.

Dr. Sawyer informs us that his inspiration and motivation for his thoughts comes from a consideration of the Louisiana purchase. From that he derives his informing vision. The essence of a vision is a sharing with us of a view of what can be. The generation and effective communication of a vision is an essential component of leadership because it serves to elicit and motivate the commitment of personal and institutional resources.

Important in Dr. Sawyer's vision is the change from a reactive to an active approach to talent identification and development. This vision is based on a premise that we have a commitment to educate for future prosperity. Consistent with his metaphor of the Louisiana Purchase, Dr. Sawyer identifies that our expeditions will inform us and allow us to take possession of this area. What is essential here is a change from a haphazard harvest to a planned effort to increase the yield. Dr. Sawyer goes on to talk about the steps involved in such an effort, specifically that of the formation of a national data base. Dr. Sawyer addresses some of the difficulties in achieving this step such as addressing points of governance and coordination. In addition a modest beginning step of facilitating collaboration among two of the four current regional talent searches is suggested.

From my viewpoint what is important is that the national data base is necessary but not sufficient in and of itself to accomplish the vision that Dr. Sawyer has outlined. The national data base is not the endpoint, but an essential vehicle for accomplishing the goals of guiding the harvest and evaluating its yield.

The most critical elements in the formation of a national data base that will serve to actualize the vision of an active effort to develop talent are the expeditions. These will reflect and constitute the conceptual framework that will underlay the national data base. The expeditions can be seen as guided by a series of critical questions:

- What is the nature of this natural resource, talent, that we are searching for and endeavoring to foster?
- What are its component parts?
- How is it engendered?
- How much stability and change exist in this resource over time?
- How is it manifested at different phases in the life span?

- Is early identification warranted--is it wise? That is, what do we know about the impact of early identification?

- What is the best time to identity and for what purposes?

- What biological and psychosocial processes are associated with stability and change?

- What are the precursors, markers, and correlates within the individual and his/her family that are associated with talent?

- What challenges are necessary, and when, to stimulate development of commitment, leadership, and self-esteem?

The quality of the expedition will be a function of the extent to which the guiding questions are theoretically and empirically driven. There are a number of theoretical perspectives that are likely to be useful in looking back, and examining concurrent relationships, and in looking toward outcome.

Thus, to plan the expedition we need to know what to look for and where and when to look for it. To plan and accomplish these expeditions it is also necessary to elicit and maintain the commitment of scholars, practitioners, and policy makers who have been systematically considering the large question and/or some of its likely component parts. That is, we must bring talent to bare on these questions and that talent must be multidisciplinary including biomedical and behavioral perspectives. We need to be able to utilize University, foundation, and federal resources to promote the formation of a number of collaborative multidisciplinary, expeditionary groups.

I know from first hand experience of the hard work that is necessary to forget such genuinely collaborative multidisciplinary efforts. I also know from first hand experience of the rewards and satisfactions that can come from that process. There are other experiences that we can look to for guidance in this process. We have been successful in this country in establishing national collaborative projects such as the National Collaborative Infant Project in the early 1970's. In addition, foundations have considerable experience in putting together networks to address areas of interest.

Finally, I would like to conclude by saying that these working groups will be the necessary engines, fueled and renewed by the excitement of committed investigators pursuing meaningful questions, that will develop a national data base and use it to foster the development of the national resource of talent.

Discussant Reaction:
Purchase and Possession: A National Database for the Scientifically, Mathematically and Technologically Talented

E. James Maxey

First, I'd like to thank Dr. Sawyer for his insightful comments. An important point that he made was the importance of a proactive effort in identifying and developing the potential of our country's talented young people. Too often, in the past few decades, the educational establishment has reacted in a sort of panic to the triumphs of other nations in areas such as space exploration and technology. The launch of Sputnik in 1957 shocked America into the realization that we were not number one in technology. We all recall the tremendous interest in the promotion of science and mathematics through the National Defense Education. Crisis solutions were proposed and, perhaps, their implementation begun; but too often, when the initial shock had worn off, these educational initiatives were abandoned. Money was made available to local school districts to improve the quality of instruction in math and science, textbooks were rewritten to introduce more modern concepts. Special textbooks were developed for biology, chemistry, and physics. New teaching aids were made available as well--calculators, slide rules, and new laboratories. This conference, I sincerely hope and believe, represents a new commitment to long-range educational goals: to seek out and nurture talent wherever it may be found, and to do this in the most effective way to provide opportunities for our young people to maximize their talents.

The concept of a national database that will enable researchers to examine the nature of talent and the ways in which talent may be encouraged and developed is one that I welcome and support. Dr. Sawyer has not underestimated the logistical difficulties of developing and using such a database.

In 1965 Dr. E. F. Lindquist, University of Iowa, developed the Card Pac system to collect and record academic development of all pupils in the elementary and secondary schools of Iowa. Test scores (ITBS and other measures of ability), courses taken, grades earned, and other teacher evaluations were collected on a yearly basis. The data were submitted by local schools on optical scan cards to the Iowa Educational Information Center (IEIC). IEIC was a non-profit organization developed by Lindquist to monitor the academic development of students, and the professional development of teachers. The optical scan data were processed by the Measurement Research Center (another test scoring business developed by Lindquist). Researchers and school officials were able to access the information available at IEIC to study issues related to

- Student achievement related to demographic characteristics
- Change in academic development over time
- Student/pupil ratios among schools
- Curriculum change
- Professional development of staff in the schools of Iowa

Lindquist had visions of such an information center being expanded to a national repository of important educational facts on students, faculty, and local schools.

The IEIC was certainly innovative, but the collection of the educational statistics on students, faculty, and institutions was very labor intensive. Local school officials cooperated but did not gain many immediate benefits. Collection of the data was very expensive, and after the three to five years of outside funding used to build the information center had ended, IEIC had to be significantly changed. Finally, the collection of such data ended about 1970-1971.

The process of collecting similar data today could be accomplished using microcomputer technology. It would be possible for local schools to submit data to a national information center on a floppy disc--using a prescribed format. By collecting information at the student level for children at grade six and above, it would be possible to help colleges, industry, and private research foundations identify pupils who could benefit from specific educational and work/research activities prior to finishing high school. Such activities would enable educators and industry to promote awareness activities among subgroups of the pupil population that currently do not seriously consider advanced education (minorities, children in rural areas, children from low income families). The highest professional standards must be maintained in ensuring the accuracy and usefulness of the data collected, in managing the technical aspects of data storage, and in monitoring the professional qualifications and ethics of those researchers and educators who will be allowed access to the data.

It might be desirable to establish such a database in a neutral location, not affiliated with any educational institution. Such a process would ensure that all educational institutions would have to meet the same standards for access to student information. The national repository of talent information on young people could be located in a nonprofit agency not connected to the federal government. The database on talent could be supervised by a board of professional educators from both the secondary and postsecondary levels.

Funding the national database on talented youth might be supported by private business and the philanthropy of private individuals. In addition, students might be asked to pay an initial fee to have talent information recorded in the database.

Both educational institutions and private industry might develop programs and services to motivate talented young people to explore educational career opportunities from grade seven through grade twelve. Such a program might enable business and industry to promote stronger awareness of opportunities for talented youth in highly technical fields. Educational experiences such as those now available at Duke and other universities might be made available within businesses such as IBM, General Motors, and AT&T. When these talented youth become old enough to hold jobs, businesses might promote learning and work opportunities for students during the academic school year as well as during the summer. Such efforts might provide greater awareness of the need for innovative improvements in all areas of technology.

Although I've been associated with a major testing company for almost my entire professional life, I've spent much of that time reminding educators and legislators that, while test scores can be a *convenient and valuable* source of information, we should not fall into the trap of assuming that they are the *only* source of information. I hope that future plans for research by the persons here today, and by others, will include studying the many different ways in which talent can be manifested and the different ways in which we can identify talented individuals. Perhaps we should think of the development of a national repository of information on young people talented in areas such as the fine arts, performing arts, athletics, mathematics, science, and technology.

Although this conference is focused on the special needs of our most academically talented young people, we need to keep in mind that all talents are valuable, and that all people, in one way or another, are talented. In a society such as our own, we have the resources to provide for the special needs of one group while also providing opportunities for those who may be less academically talented to develop their own skills to the fullest extent.

THE FEDERAL REPUBLIC OF GERMANY'S RESPONSE TO THE NEED FOR TALENT IN MATHEMATICS, SCIENCE AND TECHNOLOGY

Dr. iur. Ernst August Blanke

Two preliminary remarks:

- In the Federal Republic of Germany, too, mathematicians and scientists are trained solely at universities. In contrast, there are many possibilities for training technicians even below the university level, particularly if the aim is to provide training oriented to practical requirement. This paper merely refers to engineers who have graduated from a university.

- Secondly, there is a wide variety of employment possibilities for mathematicians, scientists and engineers and the requirements of the employment system are quite different. This is why a comprehensive reply might, to a certain extent, be inaccurate.

1. Introduction

Germany's response to the need for talent in specific scientific fields can be understood only against the background of the present and probable future requirements of the German employment system and--in this context--major basic political deliberations. For this reason, these requirements and basic deliberations are discussed first.

2. The Present and Anticipated Future Employment Situation: The Requirements Set by the Employment System

2.1 At present, an annual average of approximately 27 million persons are gainfully employed in the Federal Republic of Germany. Of this number, approximately 580,000 (approximately 2 percent) are mathematicians, scientists and engineers. In 1986 approximately 43,000 persons graduated in these subjects from universities. That is approximately 8 percent of the number of gainfully employed persons with thse training qualifications. Thus, the number of persons entering these professions each year is far higher than the number of those with corresponding qualifications who are leaving the professions.

In the same year, approximately 25,000 persons were registered as being unemployed - that is approximately 4.4 percent of the number of gainfully employed persons with the same training qualifications. *At the moment*, it would appear that the *situation on the labor market* for this group is relatively *balanced and favorable.*

2.2 The Anticipated Need

The experience gained in the Federal Republic of Germany in the seventies on the basis of isolated prognoses of the employment market for specific professions led to the conclusion that it is not possible to make reliable prognoses. There are too many imponderable factors with regard to the preliminary assessment of, for example, economic growth or the effects of technological changes on economic, production and occupational structures and therefore also on the qualification requirements of the employment system. The solution today seems to be the application of consistent model calculations by which an attempt will be made to estimate general development trends and thus also to identify in good time potential imbalances between supply and demand with regard to specific qualifications.

In the Federal Republic of Germany, there is a comprehensive model calculation of this nature which provides an advance estimate of manpower requirements until the year 2000 with regard to numbers, occupations and qualifications, giving particular consideration to the technological development.

- The application of information technology is expected to result in a major *change* in the *structure of branches* of the economy: there will be a considerable expansion in the service sector, whereas the sectors of agriculture and production will decline.
- Moreover, the major changes will take place in the *structures of production and organization.* Thus executives in particular will be required to have basic technical knowledge, the ability to apply technology economically and handle comprehensive planning strategies expertly.
- As far as *occupational structures* are concerned, a rapid and relatively sharp increase is expected in executive and management tasks.

In view of these anticipated changes, it is expected that, until the year 2000, the Federal Republic of Germany will experience an increase in the proportion of positions for university graduates from approximately 8.5% to 13 to 15%. There will certainly be a disproportionate increase in the sector of information technology and related occupations, that is, precisely in that group of preparatory training programs discussed here. **A total increase** from 560,000 persons in 1985 to approximately 1 million persons in the year 2000 is expected.

2.3 New Entrants to These Professions

The extent to which this anticipated need will be covered can be forecast with considerable certainty. Most of those who will be gainfully employed in the year 2000 are already trained or are presently undergoing training in relevant study courses. The forecast gains reliability from the fact that, as a consequence of the low proportion of female students, an employment rate of virtually 100 percent can be assumed.

During the past few years, the number of these recruits has increased considerably in the case of mathematicians, scientists and engineers, namely, by 15 percent from 1975 until 1985. It is to be expected that this increase will continue, probably by about 40 percent from 1975 until 1992.

This *favorable development will continue* since it is common knowledge that there are excellent employment opportunities for graduates from these study courses and experience has shown that would-be students are quick to enroll for such studies.

2.4 Conclusion

On the whole, on the basis of a comprehensive examination of the situation until the year 2000 with regard to the employment of university graduates in the Federal Republic of Germany, it can be assumed that supply and demand will be generally balanced.

In principle, this applies also to mathematicians, scientists and engineers. However, with regard to this group, it must be admitted that despite of the general balance I have just mentioned there may be imbalances in individual occupational sectors or local regions. In order to prevent a shortage of personnel in information technology and related professions--which would be extremely damaging to the economic development--the Federal Government has advocated the development of such study places and unrestricted access to them. In view of these measures and because study applicants are aware of the excellent employment and career opportunities open to them, it is assumed that in this field, too, there will be a *quantitatively adequate number of new graduates.*

In view of the excellent training programs and stringent examination requirements under our higher education system there is also no reason to doubt that, on average, new graduates *will be qualitatively adequate,* too.

3. Fostering the Highly Talented

3.1 The question is whether we can be satisfied with this. An international comparison reveals that the standard of living in the Federal Republic of Germany is extremely high. This also applies to those members of the German population who depend on transfer income which have to be provided by heavy taxation and social contributions of the respective groups of gainfully employed persons. In 1986, its share of the gross national product amounted to 39.3 percent. In the USA it amounted to 28.9 percent--a figure which does not even take into account the effects of the 1986 U.S. tax reform.

Germany has to work for this standard of living, to quite a considerable extent, in hard competition on the world market. Its export quota amounts to more than 30 percent--in comparison, that of the USA is approximately 7%. Competition is becoming increasingly tough. The number of highly efficient industrialized countries has increased and, therefore, also the number of competitors.

In order merely to maintain our standard of living, a constant stream of more intelligent products, production techniques, and services must be offered. In the long run, this will not be effected on the strength of average scientific and technical performance. Outstanding achievements--particularly also in the field of basic research--are required. It must, therefore, be the task and goal to attain such achievements--or, put more precisely--to demand of the appropriately qualified citizens to devote their expertise to this end.

3.2 The resulting challenge and promotion of highly gifted students--particularly in the fields of mathematics, science and technology has been recognized since the early eighties in the Federal Republic of Germany as a major task for education. On the one hand, this particular point in time can be explained by the fact that throughout Europe the awareness of the importance of this issue had increased. On the other hand, the political majority in the Federal Republic of Germany changed at that time: social democratic policy in the field of education had a very strong orientation to the concepts of equality and special care and assistance of the disadvantaged. In contrast, the policy pursued by the Christian democratic-liberal coalition aims to identify and recognize different talents and to encourage these appropriately by offering differentiated education programs. The Government does not believe that highly talented students are able to make their way alone unaided. This goes to show that active promotion of highly talented students is called for.

To rule out any misunderstanding from the start: The encouragement of outstanding achievements to the advantage of society--including economic benefits--is just one of the aims of Federal Government's promotion of highly gifted students. The Government gives priority to the individual, human aspect being convinced that the full development of a particular talent is part of a fulfilled life.

4. Measures for Promoting the Highly Talented

In illustrating the promotion measures, those measures can be disregarded which concern pupils who are particularly talented in the fields of art and sports or who show particular psychomotor and social skills. The measures addressed to students highly talented in these fields toughly differ from those addressed to academically gifted. In contrast, the measures addressed to the academically talented--particularly in the higher education sector--will hardly differ whether they are arranged for mathematically, scientifically and technically or for those highly gifted in the field of humanities. Therefore, it is allowed to describe the measures addressed to the academically talented at all.

4.1 One of the most pressing tasks in the Federal Republic is that of *arousing and increasing the awareness* of the public--in particular of parents, teachers and older pupils--of the justification and necessity of special promotion for highly gifted students. The services of education policy makers and experts in the fields of pedagogics, psychology, medicine, economics and administration must be won for scientific research and practical work.

4.2 The Individual Promotion Measures

For the adolescents aged between 16 and 19 years who are preparing themselves at high school (in Germany called Gymnasium) for access to higher education or who are already undergoing vocational training there are several extremely demanding *federal competitions* in the fields of mathematics, chemistry, physics, information science and also in foreign languages and history.

These talent competitions are an invitation to young people to test and develop their particular aptitudes and skills and thus enhance the whole of their personality.

The most important young researcher's competition in the Federal Republic of Germany is "Jugend forscht" ("Young researchers"). In this competition, participants do not compete against each other in the fulfilment of particular tasks; on the contrary, they submit to a jury scientific and technical projects which they have undertaken themselves of their own accord.

The competitions are usually at three levels: first at the regional level, then at the Lander level, and finally at the federal level. In the year 1987 approximately 90,000 young persons participated in these competitions. The national winners are admitted to the highly esteemed German National Scholarship Foundation which gives them intensive guidance and assistance, also financial assistance, during their studies. The national winners in the Federal Republic of Germany are sent to participate in the international competitions ("Olympics").

At the school level a growing number of additional *working groups* are being set up with increasing success--as scientific evaluation studies reveal. A prerequisite for participation in these working groups is high performance, motivation and ability.

In the USA, we learned the role and usefulness of special *summer courses* for highly talented students. We have been informed by participants in the Federal German competitions that these highly gifted adolescents miss the exchange of views and experience with young people of similar interests and a high level of knowledge. The Federal Ministry of Education and Science is therefore engaging in experiments concerning the organization of such summer camps.

A further important activity takes place in the field of *inservice training for teachers.* They have not only to be convinced of the necessity of such initiatives already mentioned. They must also be enabled to identify special talent as early as possible and provide professional as well as sensitive support. This includes the provision of specialized knowledge and special teaching materials.

4.3 In the *higher education sector,* by tradition the most intensive form of promotion is provided by the student's direct contact with professors and their assistants--a contact which increases as the study course progresses and as the student acquires greater skills and knowledge. The admission of highly talented students to special study programs and their direct involvement in research activities are certainly good means to create excellence both in the Federal Republic of Germany and in the USA.

In order to explain *specific promotion measures* with regard to the structure of academic institutions and teaching, a brief reference to the differences between the German and U.S. higher education systems must be made. There is no order of priority among the universities.

Then, uniform coherent study courses are instituted in the different disciplines which lead to final examinations held by the university or the state. In principle, each holder of the Abitur certificate is entitled to enroll for these uniform study courses and for all those who are interested in the respective specialized field it constitutes the actual study phase.
Efforts to introduce increased promotion of highly talented students start by criticism of the basic structure already described of German higher education institutions and with the desire to change them:

- Increased *qualitative competition between the faculties* at different universities; the amendment in 1985 to the Framework Act for Higher Education created the initial prerequisites to this end;

- Increased *participation by the faculties* with regard *to the admission of students* to higher education studies on the basis of talent and aptitude; a start was made in this respect in 1986 in the field of medicine when the faculties were involved in the selection of 15 percent of the overall number of freshmen;

- The provision of *specific study programs* for particularly talented students; the amendment to the Framework Act for Higher Education just mentioned made it possible to establish such study programs.

Moreover, the "Science Council"--a highly esteemed body advising the Federal and Lavender governments among other things on the development of higher education institutions--has recommended that *graduate colleges* be set up. On completion of generally accessible study courses, these colleges are to promote particularly well qualified young scientists working in research groups devoted to specific topics over a period of two to three years.

Even in the sector of the extremely conventional higher education institutions, there is a trend towards the provision of increased promotion for highly talented students.

For the sake of completeness, there are at least eight *foundations* which devote their efforts to *talent promotion in the higher education sector.* The largest and most well-known of these institutions is the German National Scholarship Foundation. Private foundations have been set up by the Protestant and Roman Catholic Churches, the political parties, and trade unions. Their task, in addition to giving financial aid, is to provide a certain amount of academic guidance. In particular, however, their intention is to prepare outstandingly qualified students for responsible participation in cultural, political and social tasks in society.

5. **Research**

Research on the talent has been a central concern in the fields of psychology and pedagogics since the beginning of this century. On the other hand, it is only recently that the phenomenon of outstanding talent has attracted particular scientific attention. It is now important that there is the opportunity to transfer to Germany's basic cultural situation and basic policy principles the knowledge and techniques elaborated in other countries for the identification and promotion of specially gifted students.

The individual research projects introduced by the Federal Ministry of Education and Science concern topics ranging from studies on the various ways in which special talent is manifested and the structure of intelligence, the diagnosis of outstanding talent with the aid of new procedures, the role played by aptitudes and environmental influences and the course of development of outstanding talent to the testing of suitable timing and methods of promotion. Above and beyond this, activities have been promoted which concern the connection between outstanding talent and motivation structure.

At the moment, there are *three problem complexes:*

First, with regard to a specific type of talent (in concrete terms: technical creativity) we intend to find ways for identification, consulting, promotion both within and outside schools including distance study programs, and the training of third parties for the provision of promotion. The aim is to provide for this important group of highly talented students guidelines which are as complete and intelligible as possible. Because of this, *a model is to be created for* similar *guidelines* for other types of outstanding talent. Of course, the guidelines will be partly different--especially with regard to the identification of exceptional talent. It is important that a complete concept can be presented for the treatment of specially talented students. Professor K. Heller, professor of psychology at the University of Munich, has taken on this task. He is cooperating with the Psychological Institute of the Academic Sinica in Bejing.

The second problem, which is still important even in the wake of the general political discussion on equality for women, is the unusually low proportion of women among mathematicians, scientists, and engineers in general and, in particular, in the numbers of those who demonstrate special achievements. It is obviously noticeable from the small number of female participants in our competitions in the fields of mathematics and science. The Federal Government wants to know the reasons why: Is it due to aptitude, traditional role-playing or repression during special phases of development? It wants to know whether this can be changed and how to do it. The Federal Government requested the foundation, "Young Researchers," and Professor Wieczerkowski from the University of Hamburg to investigate these correlations. This problem complex seems to be of international importance and, therefore, a challenge to all.

A third research topic, *leisure time*--the time which the individual is free to plan as he/she pleases--offers particular opportunities for developing talents and skills, creativity, and the capacity for innovation. By its very nature, it is precisely leisure time which gives special chances to the highly talented and is, therefore, of major importance for the development of their gifts. Until now, no studies have been devoted to the ways in which highly talented persons use their leisure time. Therefore, an investigation of the leisure time pursuits and of the relevant general conditions is being undertaken. The goal is to produce recommendations for young people to use their leisure time in order to optimize their aptitudes. An international group of experts under the chairpersonship of Professor Heller of the University of Munich has now started this research. The Federal Government welcomes this initiative and gives strong support to this project.

CURRENT FEDERAL EDUCATION POLICY REGARDING THE ACADEMNICALLY TALENTED IN MATHEMATICS, SCIENCE AND TECHNOLOGY

Krista J. Stewart

The purpose of this paper is to describe the federal policy regarding education of the academically talented as it relates to mathematics, science and technology. This task is a reasonable one in that some rather clear trends appear to be emerging. The focus will be on describing those trends and how they have developed.

Before beginning the main focus of this paper, however, a number of points need to be made as a means for laying the groundwork for this discussion. First, consideration must be given to how one might go about determining federal policy. Basically, federal policy might best be thought of as coming from two sources, the Legislative and the Executive branches. Legislative policy is reflected in committee reports, floor statements, news releases, proposed bills, authorizing legislation that is passed, and ultimately in funds that are appropriated. Executive policy, on the other hand, is reflected in documents and statements coming from the Executive branch, in bills that are signed or vetoed, and in the budget submitted by the President to the Congress. In this paper, conclusions regarding federal policy will be drawn from examination of various documents, statements, and legislative efforts.

During this discussion of education of the academically talented in mathematics, science and technology, several points must be kept in mind. First, the 100th Congress has been considering a number of pieces of legislation that have particular relevance for this topic. In many cases, House and Senate versions of bills have differed slightly, representing somewhat differing policy positions. This point will be discussed in more detail when particular legislative directions are discussed.

A second point to keep in mind is that although much attention is being given both to the academically gifted and talented and to mathematics, science, and technology, only rarely are those topics addressed in the same breath. As the various legislative efforts are discussed, attention will be given to how these areas are being addressed.

A final point to keep in mind when considering federal education policy is that only an estimated 8.7 percent of the total expenditures for all levels of education (elementary, secondary and postsecondary) are contributed by the Federal Government; the total Federal expenditure for elementary and secondary education is only 6.1 percent (Department of Education, 1988). In the overall picture, the amount contributed by the Federal Government seems small. The major role of the Federal Government, however, is not one of paying for education but rather one of helping States meet the needs of poor and disadvantaged children and underserved populations, providing leadership on educational issues and problems that are national in scope, and assisting State and local efforts in raising the overall quality of education (Department of Education, 1988). This paper will focus on how the Federal Government, despite its relatively small financial contribution, has had input into education of the academically gifted in mathematics, science, and technology.

Current Legislative Agenda

This is an active year for education legislation. The main themes in the education legislation are creating "equity" and "access," providing assistance in areas of national priority, and promoting quality. Moreover, emphasis is being given to the critical role education plays in our economic strength and national security (U. S. Senate, 1987). Many of the proposed bills address education of the gifted and talented and the issue of education in science, mathematics, and technology as means for meeting these priorities. Although many of the pieces of legislation were originally introduced as free-standing bills, some have also been folded into other broader omnibus bills. The most active consideration has been given to those bills that have been folded into the omnibus elementary and secondary education bills and the education portion of the trade bills.

The primary piece of education legislation in the 100th Congress is the omnibus primary and secondary education bill, which was introduced in the House as H. R. 5, "The School Improvement Act of 1987", and in the Senate as S. 373, the "Robert T. Stafford Elementary and Secondary Education Improvement Act of 1987." These bills were originally introduced as simple extensions through 1993 of the authorization of Chapters 1 and 2 of the Education Consolidation and Improvement Act. Additional reauthorization bills were used as sources of amendments and provided the basis for the components of the different omnibus bills (U. S. House of Representative, 1987b; U. S. Senate, 1987), with a vote of 401 to 1. On December l, 1987, S. 373 was incorporated in H. R. 5 as an amendment (i.e., S. 373 was given the number H. R. 5), and H. R. 5 was passed in lieu of S. 373 by a vote of 97 to 1.

After passing the House and Senate, these bills were sent to a Conference Committee in order that differences in the two bills could be resolved. Subsequently, the language agreed upon in the conference, in the legislation now entitled the "Augustus F. Hawkins--Robert T. Stafford Elementary and Secondary School Improvement Amendments of 1988," was passed by the House and Senate (Conference Report, 1988). The bill was signed into law by the President on April 28, 1988.

In the present discussion, an attempt will be made to note and explain some of the differences between the original House and Senate bills. For the sake of clarity in this paper, the Senate bill will be referred to by the number under which it was passed (H. R. 5). In addition, final agreements reached during the conference will be indicated.

A number of education proposals have also included in the trade bill resulting in a certain amount of overlap between the education bill and the trade bill. The education provisions in the House version of the trade bill are included in Title V, "Education and Training for American Competitiveness." The House bill, H. R. 3, the Trade and Export Enhancement Act of 1987, was passed by the House on April 30, 1987. The Senate version of H. R. 3 was amended and passed by the Senate in lieu of S. 1420, the Omnibus Trade and Competitiveness Act of 1987. One reason for including programs in more than one bill is to increase the likelihood of their being signed into law. Although from the beginning the future of the education bill looked bright, President Reagan repeatedly threatened to veto the trade bill, though not for reasons relating to the education programs (e.g., Auerbach, 1988). All programs that are of relevance to the present discussion that are included in the trade bill are also included in some form in the omnibus elementary and secondary education bill. Thus, primary attention will be given to the education legislation, though programs included in both the education and trade bills will be noted.

In this paper, legislation in two categories will be examined separately: that in gifted and talented education and that in education in mathematics, science, and technology. These areas will be examined separately because no program gives a clearly combined focus. Overlap, where it exists, will be indicated.

Gifted and Talented

During the 100th Congress, the greatest emphasis to date has been put on education of the gifted and talented. This focus appears to be related primarily to increasing concern about the U. S.'s rank among world powers. In legislation for the gifted and talented, the consistent theme that runs throughout is one of the need to make sure that we are educating our best and brightest in order to maintain the U. S.'s competitive position as a world leader.

Probably the strongest proponent in the Senate of programs for the gifted and talented has been Bill Bradley, who has introduced gifted and talented education legislation during the last three Congresses. In his floor statement at the time of introducing S. 303 in the 100th Congress, Bradley noted that the Federal Government is currently playing virtually no role in educating the gifted and talented. He remarked in closing:

> Gifted and talented children represent an invaluable national resource, one that remains sadly underdeveloped. I truly believe our leadership position in the world depends on our commitment to our youth. Our goal must be to do everything in our power to help all students reach their potential level of intellectual development. Special attention to gifted and talented students is called for if our Nation is to maintain and improve its position as a world leader in technology, the sciences, the humanities, and the arts (*Congressional Record*, 1987, S635).

A strong proponent of gifted and talented education in the House of Representatives has been Mario Biaggi. Biaggi has emphasized the importance of providing more effective and more specific services to the Nation's gifted and has described gifted and talented students as "students who could very well hold the key to the future of our nation and that of the entire world" (*Congressional Record*, 1987, E1450).

During the 100th Congress, several free-standing bills regarding education of the gifted and talented have been proposed, some of which subsequently have been folded into other pieces of legislation. As was mentioned earlier, the process of proposing legislation in several forms and through several vehicles increases the likelihood that the legislation ultimately will pass in some form. This section will examine the provisions in the various pieces of gifted and talented legislation that have been proposed during the 100th Congress.

Jacob K. Javits Gifted and Talented Children and Youth Education Act. The primary piece of gifted education legislation to be introduced in the 100th Congress is the "Jacob K. Javits Gifted and Talented Children and Youth Education Act." This legislation was proposed in the House on January 8, 1987, by Mario Biaggi along with 104 cosponsors as H. R. 543. The companion bill was introduced in the Senate by Bill Bradley as S. 303 on January 12, 1987, with 26 cosponsors. H. R. 543 was included in H. R. 5 and S. 303 was included in S. 373. Although several other pieces in each of the omnibus bills make reference to education for the gifted and talented, this piece of legislation is the only one to give primary focus to gifted and talented.

H. R. 543 appeared as Title IV in H. R. 5 and maintained its same title, the "Jacob K. Javits Gifted and Talented Children and Youth Education Act of 1987." The authorization level in the bill was $25 million for fiscal year 1988 and such sums as may be necessary for each of the five subsequent fiscal years. Authorization was included for fiscal year 1988 with the optimistic view that this legislation would pass by the time the fiscal year 1988 budget was completed. According to this legislation, authorized funds were to be used to make grants or contracts to State and local educational agencies, institutions of higher education, and other public and private organizations to assist them in carrying out programs authorized by this section. Programs or projects could include both pre-service and in-service training programs for teachers of gifted students, model programs for the identification and education of gifted and talented children and youth, and for other programs that would strengthen the capability of State educational agencies and institutions of higher education to improve identification and education of the gifted and talented. In addition, this Part would establish a National Center for Research and Development in the Education of Gifted and Talented Children and Youth (a provision also included in the Senate version of the trade bill), the purpose of which would be to stimulate high-quality research that would assist in identifying and serving gifted students in innovative ways. The Secretary of Education would be required to establish an administrative unit within the Department of Education to administer programs authorized by this legislation, coordinate all programs for the gifted and talented, provide national leadership in education of the gifted. Also, the Secretary of Education would be required to appoint a five-person advisory committee to advise on the administration of this Title.

The Senate version of this legislation was included in "Part D" under "Title II" of S. 373 and was introduced at the "Jacob K. Javitis Gifted and Talented Students Act of 1987." The same provisions were made as in the House version except that authorization levels were set at $15 million for fiscal year 1989, $15.8 million for fiscal year 1990, $16.6 million for fiscal year 1991, $17.4 million for fiscal year 1992, and $18.3 million for fiscal year 1993. The Senate version required that at least half of the grants under this Part be awarded to projects that would serve the economically disadvantaged. Also, in the Senate version, the requirement for the advisory committee to the Secretary was not included.

The final version of the legislation agreed upon in conference is entitled the "Jacob K. Javits Gifted and Talented Students Education Act of 1988" (Title IV--Special Programs, Part B--Gifted and Talented Children). The authorization level has been set at $20 million and such sums as necessary through 1993. Parts common to both the House and Senate bills are included in the final version. The advisory committee to the Secretary, however, has not been included in the final language; throughout H. R. 5, advisory committees have been eliminated because they create a drain on resources that could be used for services. Instead, the bill indicates that the Secretary would be expected to consult with experts in the field of education of the gifted and talented regarding the administration of this Title. The set-aside for programs for the educationally disadvantaged has been maintained (Conference Report, 1988).

The "Jacob K. Javits Gifted and Talented Students Act of 1988" is the primary piece of legislation for gifted and talented in the omnibus education bills. Funding for gifted and talented, however, is also found in several other portions of these bills.

Chapter 2 Block Grants. Federal funds that currently are being used for gifted and talented programs come primarily from Chapter 2 block grants. Chapter 2 funds are distributed to State on the basis of school-aged population, and the funds may be used by the State and local education agencies for any of the more than 30 antecedent programs, or for other educational purposes, one of which is for programs for the gifted and talented (U. S. Senate, 1987).

The Chapter 2 program has been reauthorized in the current omnibus education legislation. In the Committee report for S. 373 (U. S. Senate, 1987), concern was expressed that there have been insufficient accountability requirements for these funds and that in fact the use of funds in some districts has been for general education purposes, leaving specific needs unmet by State and local expenditures. In response to this concern, the Senate bill included language that would have targeted funds by restricting the use of Chapter 2 expenditures to six broad areas. State and local educational agencies would have continued to have the same degree of flexibility in determining their use within the six categories. Programs for gifted and talented was one of the six designated areas. Authorization levels in the bill were $580 million for fiscal year 1991, $672 million for fiscal year 1991, and $706 million for fiscal year 1993.

The House took a slightly different approach to Chapter 2 in H. R. 5. The rationale in the Committee report was as follows:

> First, some studies have been critical of Chapter 2's "unfocused" nature. The Committee did not wish to retarget Chapter 2 on a few specific areas, as has been proposed in some quarters. The Committee's response has been to make Chapter 2 a better vehicle for school improvement by recasting the use of funds in general terms, but with an identifiable theme of improving quality and promoting innovation. These changes are in keeping with the national reports that urge the Federal government to take a leadership role in school excellence and reform (U. S. House of Representatives, 1987, p. 50).

In order to provide State and local agencies with some guidance in appropriate uses of the funds to meet the theme of improving quality, the bill outlined five general areas. One of these general areas was "special projects." H. R. 5 listed several examples of possible special project activities, one of which was gifted and talented education (the others were youth suicide prevention, technology education, community education, and career education). Thus, specific reference to gifted and talented was made under the proposed legislation for Chapter 2, but the emphasis was less focused and less clear than it was in the Senate bill. H. R. 5 authorized Chapter 2 at $580 million for fiscal year 1988, and such sums through 1993. Thus, the authorization levels were similar to that in the Senate bill.

In the language agreed upon in the conference on Chapter 2, authorization levels are those from the Senate-passed bill. In addition, six categories of use that are somewhat different from either those in the original House or Senate versions are included. The sixth category is for "other innovative projects which would enhance the educational programs and climate of the school, including programs for gifted and talented students, technology education programs, early childhood education programs, community education, and programs for youth suicide prevention" (Conference Report, 1988, p. 83). The fact that other popular programs are included in this category along with gifted and talented may serve to dilute the emphasis on gifted and talented education as a target area. Whether or not more Chapter 2 money will be used for gifted and talented education than was used previously remains to be seen. What originally appeared to be promising legislation for gifted and talented, particularly in the Senate version, may in the end result in little change from the present circumstances.

Gifted and Talented Education for Special Groups. Several bills have been offered during the 100th Congress that would provide for education of the gifted and talented from special groups. S. 150, introduced by Senator Inouye, would provide financial assistance to community colleges and to Kamehameha Schools/Bishop Estate for demonstration grants designed to address the special needs of gifted and talented elementary and secondary school students who are Indian or Native Hawaiian. S. 360, also introduced by Senator Inouye, a bill to improve the status of Native Hawaiians, contains a gifted and talented education component. This bill was passed by the Senate, but was also included in S. 373 as Title X. Section 10006 of Title X made provision for a native Hawaiian gifted and talented demonstration program to address the special needs of Native Hawaiian elementary and secondary students. In addition, this Act required that the Secretary of Education facilitate the establishment of a national network of Native Hawaiians and American Indian Gifted and Talented Centers for the purpose of information sharing. Authorizations for this section were $1 million for fiscal year 1988 and for each succeeding year through 1993.

H. R. 1081, was introduced by Congressman Akaka, as a companion bill to S. 360. This bill was referred to Committee but was also included in H. R. 5 in Part E of Title VIII. The gifted and talented part of this legislation was almost identical in provisions and authorization to that in S. 373 although no requirement for a national network of Native Hawaiians and American Indians was included.

Efforts to seek funding for gifted and talented programs for Native Hawaiians has been part of a broader effort designed to help Native Hawaiian children achieve educational parity with other ethnic groups. Senators Inouye and Matsunaga have been leading this effort in the Senate for more than ten years. Results of a study conducted jointly by the U. S. Department of Education and the Kamehameha Schools/Bishop Estate published in 1983 validated the perceived urgency of the educational needs of the Native Hawaiians. These efforts finally have come to fruition by the inclusion of Education for Native Hawaiians (Title IV) in the conference agreement. With regard to gifted and talented education, both the demonstration projects and national information network are included, and the authorization level is $1 million for each fiscal year through 1993 (Conference Report, 1988).

Funding for gifted and talented education was also included in the Bilingual Education Program in both H. R. 5 and S. 373 (Title VII in both bills). In both bills one of the stated uses of the funds under this legislation was for gifted and talented programs preparatory or supplementary to programs such as those assisted under this Act. In S. 373 one of the designated research activities authorized to be assisted was "studies to determine effective and reliable methods for identifying gifted and talented students who have language proficiencies other than English" (p. 371). In addition, both bills required that the at least 16 resource centers funded by this act would gather and disseminate information on a particular area of bilingual education, one of which was bilingual education for gifted and talented limited English proficiency students and another which was mathematics and science education in bilingual programs. No specific amount of the authorized funding was set aside for gifted and talented education in either bill. In the conference agreement all of the provisions relating to gifted and talented education are maintained (Conference Report, 1988).

Mathematics, Science, and Technology Education

During the 100th Congress, greater emphasis also has been placed on education in mathematics, science, and technology. The stimulus for this emphasis is similar to that for gifted and talented education, that is, increasing concern about the U. S.'s rank among world powers in this increasingly technological society.

Education in Mathematics and Science. At the current time, the primary source of funding for mathematics and science education has been Title II of EESA. The purposes of the Current Title II under EESA are to improve instruction in mathematics, science, computer learning, and foreign languages; to increase student access to such instruction; and thereby to strengthen the Nation's economic security. The current law authorizes $350 million for fiscal year 1988 and provides that 90 percent of the annual appropriation be allocated among the States. Nine percent of the appropriation is for the Secretary of Education's discretionary grants (special consideration is given to grants for magnet schools for gifted and talented students), and 1 percent is for the outlying areas and Indian students. At least 70 percent of the State allocation is to be allocated for elementary and secondary programs. At least 70 percent of the elementary and secondary allocation is to be distributed by the State educational agency (SEA) to the local educational agencies (LEA's), half on the basis of relative public and private school enrollment and half on the basis of low-income children in public schools.

LEA's may use the funds for improving and expanding the training of teachers and other personnel in mathematics and science and, if the need is met in those areas, in computer learning (no more than 30 percent of the funds) and foreign language (no more than 15 percent of the funds). At least two-thirds of the funds reserved by the SEA for elementary and secondary programs must be used for demonstration and exemplary programs for teacher training and retraining in mathematics, science, foreign language, and computer learning; for instructional equipment and materials; for underrepresented and underserved groups and gifted and talented children (at least one-fifth of the demonstration and exemplary program funds must be used for this purpose); and for dissemination of information on exemplary programs to LEA's.

Under the current law 30 percent of each State's allotment is used by the State agencies for higher education (SAHE). Not less than 75 percent of this amount is to be awarded to higher education institutions to be used for traineeships for persons who will teach science and mathematics in secondary schools; for retraining secondary school teachers of other subjects to teach mathematics, science, foreign languages, and computer learning; and for in-service training for elementary, secondary, and vocational teachers to improve instruction in these subjects. The other 25 percent is to be used by the SAHE for cooperative programs (20 percent) and assessment of State needs, evaluation, and administration (5 percent).

The purpose of Title VI of S. 373, was to amend and reauthorize Title II of EESA. The Senate bill changed the purpose of EESA Title II by deleting the improvement of foreign language instruction as a purpose of the bill (foreign language was covered under Part B of Title VI of the omnibus bill.) But kept the focus on instruction in mathematics, science, and computer learning. Originally in S. 373, authorization levels were $330 million for fiscal year 1989, $345 million for fiscal year 1990, $365 million for fiscal year 1991, $385 million for fiscal year 1992, and $405 million for fiscal year 1993. When S. 373 went to the floor of the Senate, however, these authorization levels were cut to $280 million for fiscal year 1989, $295 million for fiscal year 1990. $315 million for fiscal year 1991, $335 million for fiscal year 1992, and $355 million for fiscal year 1993. Prior to consideration of the omnibus bill, an agreement had been made to maintain a given authorization cap on the bill. Thus, when on the floor an agreement was made to provide additional funding for two programs, money had to be taken out of other areas and was taken out of Title VI of the bill. Although this action might seem to suggest a lack of commitment to mathematics and science, the original authorization levels were far above current appropriation levels and still were given after the cut in authorization. The authorization/appropriations relationship will be discussed in greater detail in a later section of this paper.

The Senate bill provided that 95 percent of the annual appropriation was to be allocated among the States. Four percent is for the Secretary's discretionary grants (Special consideration was to be given to grants for magnet schools for the gifted), and 1 percent was for the outlying areas and Indian students. At least 75 percent of a States' allocation was to be used for elementary and secondary programs of which not less than 90 percent was to be distributed among the LEA's, half on the basis of relative public and private school enrollments and half on the basis of low-income children enrolled in public schools. No maximum was set for the share of an LEA's funds that could be used for computer learning. Of the SEA funds for elementary and secondary programs, half was to be used for demonstration and exemplary programs. Programs serving underrepresented groups and gifted and talented students were to be given special consideration, but no specific portion of the funds was set aside for these groups as in the current law. Programs for gifted and talented students could include magnet schools.

The Senate bill provided that 25 percent of each State's allocation was to be used by the SAHE for higher education programs. Of this amount not less than 95 percent was to be awarded to higher education institutions for uses similar to current law. No more than 5 percent was to be used for assessment of State needs, evaluation, and administration.

The purpose of Title II of H. R. 5 was to repeal Title II of EESA and replaces it with the Critical Skills Act. In building the rationale for the Critical Skills Act, the House Committee report noted:

> The status of mathematics and science education is still critical: Shortages of properly certified teachers still exist, teachers are still out of touch with new developments in the fields, students are still achieving below their international peers, student enrollment in advanced courses is still declining, and too many programs still lack needed mathematics and science equipment (U. S. House of Representatives, 1987b, p. 60).

The report goes on to cite data from a 1985-1986 survey by the National Science Teachers Association which found that some 7,000 high schools offered no physics course, 4,000 offered no chemistry course, 2,000 did not offer a biology course, and about 17,000 offered no earth or space science. Moreover, almost one-third of all high school students were being taught science or mathematics by teachers who were teaching the courses as their second or third field.

Title II of H. R. 5 changed the purpose of the current law by deleting references to computer learning and foreign language and focused on strengthening national security and economic competitiveness. The House report indicated that although the Committee members believed that foreign language and technology education are important, they felt that because these areas are covered in the trade legislation in H. R. 3, it was preferable not to duplicate efforts when mathematics and science educational funds have been so limited (U. S. House of Representatives, 1987b).

The House bill authorized an annual appropriation of $400 million for fiscal year 1988 and such sums as necessary through fiscal year 1993. This increase in authorization was intended to reflect the Committee's belief that these programs are a high national priority (U. S. House of Representatives, 1987b). Allocation for the States under this bill were to be 94 percent of the annual appropriation with 5 percent for the Secretary to use to make grants (No mention was made of assistance to magnet schools for gifted and talented students.), and no more than 1 percent for outlying areas and Indians students.

The House bill used a different formula for distribution of the money to the States than does current law; in addition to a State's share of population aged 5 to 17, the State's Chapter 1 allocation was to be considered in determining the allocation under this Title. This formula would be likely to direct a greater share of appropriated funds to States with substantial low income populations (Stedman, 1987). H. R. 5 provided that at least 80 percent of a State's allocation was to be distributed to LEA's for elementary and secondary programs, half on the basis of relative public and private school enrollments and half on the basis of low-income children.

The uses of funds specified in the bill were different than those in the current law. Included in the uses were teacher training (Most were in-service activities.), recruitment or retraining of minority teachers to become mathematics and science teachers; financial bonuses to be used for hiring teachers in critical mathematics and science areas; training and instructional use of computers and other telecommunications technology; improving mathematics and science curriculum; partnerships for special instructional programs in mathematics and science; academic and counseling programs to increase participation of specified minority and disadvantaged groups in mathematics and science courses; matching grants for purchasing laboratory equipment; initial funding for mathematics and science magnet schools; and leadership workshops for administrators to improve mathematics and science instruction.

Funds reserved for the SEA, half of which were to be allocated to SAHE's could be used for the following teacher training; exemplary programs to improve mathematics and science training and instruction; evaluation and improvement of State licensing and certification procedures for mathematics and science teachers; special programs to attract minorities and women to mathematics and science teaching; improvement of curriculum; coordination of mathematics and science instruction with increased high school graduation requirements; development of instructional approaches for computers and other telecommunications devices; technical assistance; and small grants to teachers for innovative projects. Not more than 5 percent of the total State grant was to be used by the State for Administration (4 percent for the SEA and 1 percent for the SAHE).

In summary, both Senate and House bills contained a Federal mathematics and science program, the Senate bill being more similar to the current EESA Title II. Both bills, however, contained some common features. Both would have appropriated funds to States by an allocation formula, focused funds primarily on teacher training, and reserved funds for grants to be made by the Secretary of Education. There were, however, substantial differences between the two bills. The Senate authorization level was significantly below that in the House bill and would not reach the current authorization level until 1993. The Senate bill deleted most references to foreign language instruction, but the House bill deleted references to both foreign language instruction and computer learning and was more specific in describing just what activities could be supported under the mathematics and science program. The House's formula for funding took into consideration a State's share of Chapter 1 allocations, a change that would likely result in a greater share of the funds being directed to States with substantial low income populations. Finally, both bills increased the elementary and secondary focus of the mathematics and science program, but the House bill made a stronger move in that direction.

The agreement on mathematics and science education that was accepted in conference is the one that had been reached during the conference on the education portion of the trade bill. In its final form the act is now called the "Dwight D. Eisenhower Mathematics and Science Education Act" and is included as Part A of Title II. The accepted purpose of this legislation was adopted from the House version and is "to strengthen the economic competitiveness and national security of the United States by improving the skills of teachers and the quality of mathematics and science in the Nation's public and private elementary and secondary schools through assistance to State educational agencies, local educational agencies, and institutions of higher education" (Conference Report, 1988, p. 95).

Authorization will be for $250 million for fiscal year 1989 and such sums as necessary through fiscal year 1993, levels lower than in either the House or Senate bills but still higher than current authorization levels. Table 1 provides a summary of the differences among current legislation, the proposed bills, and the conference agreement regarding allocation of funds for mathematics and science education. The conference language provides that 95 percent of the annual appropriations be allocated among the States; the formula for making funds available to States is the same as the one in the House bill (i.e., taking into consideration a State's share of Chapter 1 allocations). Four percent is for the Secretary of Education to make grants or enter into cooperative agreements (special consideration is to be given to agencies providing special services to historically underserved and underrepresented populations--and especially gifted and talented from within such populations--in the fields of mathematics and science), and 1 percent is for the outlying areas and Indian students. An amount equal to 75 percent of a State's allocation is to be used for elementary and secondary programs of which not less than 90 percent is to be distributed among the LEA's, half on the basis of relative public and private school enrollments and half on the basis of low-income children enrolled in public schools.

The uses of funds by LEA's accepted in the conference language are taken from both the House and Senate language. They include:

1. The expansion and improvement of pre-service training, in-service training, and retraining of teachers and other appropriate school personnel in the fields of mathematics and science, including vocational education teachers who use mathematics and science in the courses of study they teach;

2. Recruitment or retraining of minority teachers to become mathematics and science teachers;

3. Training in and instructional use of computers, video, and other telecommunications technologies as part of a mathematics and science program (which may include the purchase of computers or other telecommunications equipment in schools with an enrollment of 50 percent or more of students from low-income families after all other training needs have been met;

4. Integrating higher order analytical and problem solving skills into the mathematics and science curriculum;

5. Providing funds for grants projects for individual teachers within the local educational agency to undertake projects to improve their teaching ability or to improve the instructional materials used in their classrooms in mathematics and science (Conference Report, 1988, p. 97).

Of the SEA funds for elementary and secondary programs, half is to be used for demonstration and exemplary programs. Programs serving underrepresented groups and gifted and talented students are to be given special consideration, but no specific portion of the funds is set aside for these groups as in the current law. Programs for gifted and talented students may include assistance to magnet schools.

The conference language provides that 25 percent of each State's allocation is to be used by the SAHE for higher education programs. Of this amount not less than 95 percent is to be awarded to higher education institutions for traineeships, retraining, and in-service training. No more than 5 percent is to be used for assessment of State needs, evaluation, and administration.

Thus, compared to current law, the focus in the new legislation is on just science and mathematics. The funding formula will likely result in a greater share of the funds being directed to States with substantial low income populations. The focus on elementary and secondary mathematics and science is increased. Also, increased emphasis is placed on services to gifted and talented students; wherever underrepresented or underserved populations are mentioned in the final language, gifted and talented is added as one of the designated groups.

Partnerships in Education. Another program originally included in EESA as Title III is "Partnerships in Education for Mathematics, Science, and Engineering." The purpose of this Title is to encourage partnerships in education between the business community, institutions of higher education, and elementary and secondary schools to improve instruction in the fields of mathematics, science, and engineering and to furnish additional resources and support for research, student scholarships, and faculty exchange programs in the field of mathematics, science, and engineering. Grants for this program are to be made by the National Science Foundation, which pays the 50 percent Federal share of the cost of approved programs. This program has been authorized since 1984 and was authorized at $50 million for fiscal year 1988. No funds, however, have ever been appropriated for educational partnerships (U. S. House of Representatives, 1987b).

Both the House and Senate education bills would have reauthorized the partnership program, the House bill at $10 million for fiscal year 1988 and such sums as necessary through 1993, the Senate bill at $20 million for the same period. The House report (U. S. House of Representatives, 1987b) described the lower appropriation as more realistic in light of previous lack of appropriations.

Education partnerships are reauthorized in Section 2301 in the final conference language. The authorization is for $15 million for fiscal year 1989 and such sums as may be necessary for each of the fiscal years from 1990 to 1993. What remains to be seen is whether or not funds will be appropriated for this program (Conference Report, 1988).

Star Schools. The Star Schools Program Assistance Act is a legislative response to the national concern about the increasing numbers of young people who, based on inadequate skills in mathematics, science, and technology, are ill-equipped to survive in a highly technological society. Star Schools was a new title under the Education for Economic Security Act, Title VI in S. 373, but was not included in H. R. 5. The Star Schools Program would:

> provide demonstration grants to partnerships including educational institutions, educational agencies, and entities with telecommunication networking

> expertise. These partnerships will use telecommunications technology (satellite, microwave, fiber optic, cable technologies, and others) to deliver courses in mathematics, science, foreign language and other subject areas to elementary and secondary schools, particularly those serving disadvantaged students, those with scarce resources, and those with limited access to courses in these critical subject areas, as well as to institutions of higher learning, to teacher training centers, and to industry (U. S. Senate, 1987, p. 64).

Not only would instructional programs for students be provided through Star Schools, but also teachers, without having to leave the workplace, would receive the additional training they would need to serve their students better.

The Star School Program has particular implications for teaching mathematics and science to gifted students. Various national reports (e.g., National Science Teachers Association) have concluded that American students receive limited exposure to mathematics and science programs. In addition, the Executive Director of the National Science Teachers Association has estimated that "about 30 percent of all individuals currently teaching mathematics and science in high schools are 'either completely unqualified or severely underqualified to teach those subjects' and over 40 percent of the mathematics and science teaching force will retire by 1992" (U. S. Senate, 1987, p. 68). Many schools cannot afford to offer advanced courses to a handful of bright students, nor may teachers be able to teach those courses. As a result of Star Schools Program, more students could be provided access to courses of highest quality. In addition, teachers would be assisted in integrating telecommunication equipment and materials into their regular curriculum and would be provided with necessary training to update their skills in their subject area.

Authorization in S. 373 for the Star Schools Program was for $100 million for the period beginning October 1, 1988, and ending September 30, 1992. The stipulation was made that not less than 50% of the funds made available in any fiscal year be used to benefit local educational agencies eligible to receive assistance under Chapter 1 of the Educational Consolidation and Improvement Act.

The Star Schools Program was passed as part of S. 373. Prior to its passage in the omnibus bill, however, it had been passed by the Senate as a free-standing bill (S. 778) and as part of education portion of the trade bill. In addition, in the continuing resolution (H. J. Res. 395) Star Schools was authorized with reference to the Senate-passed H. R. 5 and funds were appropriated for fiscal year 1988. In the accepted conference language in H. R. 5, funds were appropriated for fiscal year 1988. In the accepted conference language in H. R. 5, Star Schools is authorized at $100 million for the period beginning October 1, 1987, and ending September 30, 1992 (Conference Report, 1988).

Magnet Schools. In 1972, the Emergency School Aid Act (ESAA) was created in response to federally-mandated desegregation of public schools and provided assistance to local school districts undergoing desegregation. In 1981, ESAA was one of the categorical programs to be consolidated under the ESEA Chapter 2 block grants. However, in 1984, Congress passed the Magnet Schools Assistance Act as Title VII of the Education for Economic Security Act to provide, once again, specific federal assistance to local school districts in their desegregation efforts.

The Magnet Schools program has implications for mathematics and science instruction for the gifted. The purpose of the magnet schools program is to have distinctive curricular features that are intended to attract students of different races and to reduce, eliminate, or prevent minority group isolation in schools with high proportions of minority students. One objective of magnet schools (the one of greatest relevance to the present discussion) is to provide a course of instruction that will substantially strengthen the knowledge of academic subjects.

Reauthorization of the Magnet Schools program was included as Title III in both H. R. 5 and S. 373. Stipulation was made in both bills that funding was to be used for acquisition of books, materials, and instructional equipment, including computers and for compensation of certified and licensed teachers. The expenses in these areas were to be related to improvement in several curricular areas, the first two mentioned being mathematics and science, thus giving them implicit emphasis. Although no direct mention was made of gifted and talented in this legislation, emphasis was given to strong academic programs.

Authorization levels in H. R. 5 for Magnet Schools were $115 million for fiscal year 1988 and such sums as may be necessary for each of the fiscal years 1989 through 1993. In S. 373, authorization levels were $115 million for fiscal year 1989, $121 million for fiscal year 1990, $127 million for fiscal year 1991, $133 million for fiscal year 1992, and $140 for fiscal year 1993. The Senate bill also made provision for funding a Magnet Schools Improvement Program (Part B) for which appropriations would only be made if the appropriation for Part A of the Magnet Schools legislation were equal to or exceeded $100 million. Authorization levels for Part B were to start at $35 million.

In language accepted in conference, authorization is $165 million for fiscal year 1989 and such sums as necessary for fiscal years 1990 to 1993. Additional funding under the Secretary's Fund ($135 million for fiscal year 1989 and such sums as may be necessary for fiscal year 1990 to 1993) are authorized for alternative curriculum schools having a minority composition of at least 50 percent; funds for this program, however, are not to be appropriated in any fiscal year unless the amount appropriated for Magnet Schools is equal to or exceeds $165 million (Conference Report, 1988).

Programs for Computer-Based Instruction. A new program under Part J, "The Secretary's Fund for Innovation in Education," of Title II in S. 373 was "Programs for Computer-Based Instruction." This legislation would have authorized the Secretary of Education to make grants for the purpose of strengthening and expanding computer education resources available in public and private elementary and secondary schools. The authorization, beginning at $20 million in fiscal year 1989, was for funds that would be divided among this program and four others. In H. R. 5, the Secretary's discretionary funds were available under part B of Chapter 2. The Secretary was to give priority consideration to projects of technology education. Agreements reached in conference on this legislation will be discussed in the next section.

Tests for Academic Excellence. Part C included under Title IX, Educational Assessment and Achievement, of S. 373, was one that could have potential implications for gifted students having outstanding mathematics or science achievements. This part authorized the Secretary of Education to approve or develop comprehensive tests of academic excellence to be administered to identify outstanding students who are in the eleventh grade of public and private secondary schools. In addition, the Secretary was authorized and directed to prepare a certificate for issuance to students who score at a significantly high level (as determined by the Secretary) on a test of academic excellence. Not less than $2 million in each fiscal year was to be reserved from the funds available under the General Education Provision Act to carry out the provisions in this title.

The idea of such testing is not new but was renewed with the issuance of "The Nation's Report Card," a report that came out of a study group chaired by former Tennessee Governor Lamar Alexander. In the Committee report (U. S. Senate, 1987) it is noted that such a test is envisioned as an improved means of assessing student progress and of providing state-by-state information on student strengths and weaknesses. However, the test is not intended to be mandatory either for the LEA or for any individual student.

One benefit of such a test noted by the Committee is that it could help to identify talented students who might otherwise go unrecognized. In turn, an awarded certificate might aid the student in getting a job or in gaining admission to an institution of higher learning (U. S. Senate, 1987).

The idea of such a test, however, has not gone without opposition. Opponents of a test of academic excellence say that such a test would undermine the American tradition of education as a State and local enterprise and would lead to a national standardized curriculum. Proponents, on the other hand, argue that for all practical purposes, national consensus on curriculum already exists (Fiske, 1987).

In the conference agreement, the *optional* Tests for Academic Excellence is included along with Programs for Improvement of Comprehensive School Health, Technology Education, and Programs for Computer-Based Education under the new separate section of the Secretary's Fund for Innovation in Education. This fund is authorized at $20 million and is totally discretionary giving the Secretary the authority to allocate funds in any way he sees fit (Conference Report, 1988).

Other Sources of Funding for Science and Mathematics Education

Not all funding for science and mathematics education is through the Department of Education. Other sources will be discussed.

National Science Foundation. A Science and Engineering Education Activities program is funded through the National Science Foundation. The major activities under this program are research career development, including enrichment activities for talented high school students; materials development research and informal science education; teacher preparation and enhancement, focusing on upgrading the quality of faculty teaching mathematics and science; studies and program assessment to provide a systematic understanding of science and mathematics education in the U. S.; and undergraduate science, engineering, and mathematics education.

Although there is some overlap in the Department of Education and NSF science and mathematics education programs, funding from the Department is more typically used to support programs at the State or local educational agency level while NSF funds are more likely to be used for grants awarded to colleges and universities. The necessity for coordination of these programs is recognized as indicated by a stipulation in the trade bill requiring coordination of mathematics and science education programs of the Departments of Education and Energy and the National Science Foundation.

The National Science Foundation is currently being reauthorized. Appropriations for NSF will be discussed in a later section.

Appropriations

Although authorization levels set in bills give some indication of Congress' priority for programs, the true test of commitment to a program comes from the amount of money that ultimately is appropriated to the program in a given year. Authorization sets in law a cap for the level at which a program may be funded. It is not unusual, however, for a program to be funded at half or even less than half of its authorization level. Thus, a more accurate picture of the priority being given to education of the academically gifted in mathematics, science, and technology would come from an examination of the actual amount of money being appropriated to programs.

Table 2 presents authorization and appropriation information on the programs that are currently providing primary Federal support for gifted and talented education (i.e., Chapter 2 block grants, though only a small portion of this money is spent on gifted and talented) and mathematics and science education. Both the House and Senate recommendations for fiscal year 1988 appropriations are indicated.

For Chapter 2 block grants, money that could potentially be used by States to support gifted and talented education, both the House and Senate recommended appropriation of $500 million for fiscal year 1988, the same level at which the program had been funded during fiscal year 1987. Because of across-the-board budget cuts, however, the final appropriation was set at $478.7 million, a decrease of 4.45percent from the previous year.

The authorization level for Title II of EESA for fiscal year 1988 is $350 million. Both the House and Senate made recommendations for appropriation at a level far below the authorization. Moreover, the House recommendation was $25 million below the 1987 fiscal year appropriation. The appropriation passed in the Continuing Resolution, however, resulted in a 50 percent increase in funding over fiscal year 1987. An interesting contrast here, and one that emphasizes the importance of considering appropriations rather than just authorization, is that in the current EESA reauthorization legislation, the House-proposed authorization far exceeded that of the Senate.

As was mentioned previously, Star Schools has received appropriation for fiscal year 1988, even though it had not previously been authorized. The somewhat lower appropriation in the Continuing Resolution than had been recommended by the Senate again reflects across-the-board budget cuts.

For the Science and Engineering Education Activities funded through the National Science Foundation, no fiscal year 1988 authorization was ever passed in the Senate, only by the House. The approved appropriation for fiscal year 1988 is only about $10 million below the House's fiscal year 1988 authorization level. Both the House and Senate had recommended an increase in funding compared to fiscal year 1987, although the House recommended a greater increase. The approved appropriation reflects a 40 percent increase in funding in this area in contrast to only a 3 percent increase in research funding and a 6 percent increase in the overall National Science Foundation Funding (these latter figures are provided for sake of comparison).

Comparing Department of Education funding to NSF funding, the House gave priority to NSF education activities and the Senate gave priority to EESA, Title II. Actual appropriations are much closer to authorization level for NSF than for EESA. As was true in fiscal year 1987, NSF science and engineering education funding for fiscal year 1988 is $20 million higher than EESA, Title II funding.

Looking at these programs, the substantial increases in funding relating to mathematics and science education suggests a clear commitment in this area. (Note: in the four years after NDEA was passed, nearly one billion dollars was made available to provide for the various activities under that act.) Particularly in this tight budget year, programs that have received increases of 40 to 50 percent are clearly perceived as priorities. Potentially, some of these funds could be used to improve mathematics and science education for academically gifted students although as previous discussions suggest, the current focus in Congress is on improvement of mathematics and science education for all students. Funds that potentially could be used for gifted and talented education have not been increased and, in fact, reflect across-the-board budget cuts. Thus, for fiscal year 1988, clear priority is being given to mathematics and science education although no clear emphasis is being given to mathematics and science education for the academically gifted. What will be important to note in the new education legislation once it is passed, much of which gives a priority to gifted and talented, is the appropriations that will be made for the various programs. The appropriations for fiscal year 1989 should provide a fuller picture of the focus of Federal support and priorities.

Executive Policy

Although the Congress plays an important role in determining the focus of education policy, the Executive Branch of the Federal Government also influences education policy. As was noted earlier, one consistent theme throughout the last eight years of the Reagan Presidency has been to reaffirm that the control of schools belongs to States, communities, parents, and teachers. Consolidation of categorical programs into State block grants was one of the efforts championed for this purpose.

During the Reagan Administration, numerous reports on the quality of education have been issued through the Executive Branch. The report by the National Commission of Excellence in Education (1983), *A Nation At Risk: The Imperative for Educational Reform* has already been mentioned. As was noted earlier, recommendations were made in this report regarding topics to be covered in various areas including mathematics, science, and computer science.

First Lesson: A Report on Elementary Education in America, a report made by Secretary of Education William Bennett (1986), evaluated elementary school curricula in various academic areas. Regarding mathematics, Bennett concluded,

> Children in elementary years need not only the basic computing skills, but need also to learn how to select the right strategies to solve complicated problems. Our schools face a major challenge in imparting these crucial mathematics skills and problem-solving strategies (p. 27).

In science, according to Bennett, "the challenge before science educators is to develop better means of measuring both factual knowledge and the kinds of understanding students acquire through activities" (p. 28). In discussing gifted and talented students, Bennett indicates that too often education of the gifted and talented is fragmented. He recommends moving away from "the chronological lockstep of age-grading" (p. 61) as well as providing special opportunities in a wide variety of settings.

In some sense, a sequel to *First Lesson* is *James Madison High School: A Curriculum for American Students* (Bennett, 1987). In this report Bennett outlines a high school curriculum that he feels would enable the U. S. to achieve its educational goals. In this curriculum, among other requirements students would be required to take three years of mathematics and three years of science. Bennett emphasizes, however, that neither *First Lesson* nor *James Madison High School* are intended to be a statement of Federal policy because power to mandate school curriculum does not belong to the Federal Government.

Whether or not these reports are meant to reflect policy, they do at least suggest an emphasis being given by the Executive Branch to certain aspects of education. (Because of the focus of this paper, attention has been given here only to how mathematics, science, and education of the gifted are addressed on these reports:) Other means of promoting policy are perhaps more obvious.

One way in which the Executive Branch clearly does state policy is through the President's annual budget. Table 3 provides a comparison of the President's budget requests and appropriation levels in the primary programs funding education of gifted and talented and mathematics and science education.

The President is requesting a 13 percent increase for fiscal year 1989 in Chapter 2 Block grants, the current source for Federal gifted and talented funding. This money would be made available to States and local educational agencies to continue the momentum of the current educational reform movement. However, no specific areas of use are indicated in the budget rationale (Department of Education, 1988).

The President's 1989 request for EESA Title II is the same as the current appropriation. This program, however, did have a 50 percent increase from fiscal year 1987 to fiscal year 1988. The fiscal year 1988 appropriation, however, was 50 percent above the President's 1988 request.

No funding is requested for Star Schools, a program still being considered for authorization as part of the omnibus education bill. Of interest, however, is that funding for some new education programs have been included in the President's budget, even though the pending education legislation has not yet been signed into law (e.g., Parental Choice Open Enrollment Demonstrations). No funding is included in the budget for the new gifted and talented categorical program.

For Science and Engineering Education under the National Science Foundation, the President is requesting a 12.1% increase following a 40% increase in appropriation between fiscal year 1987 and 1988. This increase is about the same as the net increase recommended in the NSF research budget but less than the increase for the NSF total budget; this later increase is primarily a reflection of the President's request for appropriations for science and technology centers.

Comparing Department of Education funding and NSF education funding, the President appears to give priority to NSF. For the last two years, the President's EESA, Title II request has been at a level equivalent to the previous year's appropriation. NSF science and engineering education requests, however, have been well above the previous year's appropriation for both years.

During the Reagan Presidency, categorical funding for gifted and talented was lost, and no other clear efforts to federally support gifted and talented education have emerged. However, gifted students, as a group that deserves special attention, have at least been acknowledged in reports coming from the Executive Branch. Mathematics and science education have received increased support, but Congress (though the appropriations passed) rather than the President (through budget requests) appears to be taking the lead in this area.

Conclusions and Recommendations

The time is one at which a clearer Federal policy regarding educating academically gifted students in mathematics, science, and technology appears to be emerging. Congressional intent, as can be discerned from Committee reports and pending legislation, is that the U. S. should provide optimal education to the best and brightest students to ensure the Nation's ability to maintain its competitive edge. This is not the first time that such a commitment to improving mathematics and science education, particularly for able students, has existed. Thirty years ago, the U. S. made a similar commitment.

One might question why this commitment is having to be made once again. Are Congressional reports merely rhetoric? Does the commitment become diffused as the Federal funds trickle down to the LEA's? Is maintaining a sustained effort for improvement impossible in the context of constantly changing Congresses and Administrations? Does conflict between the Congress and the Administration slow progress? Are the problems ones that are relatively unrelated to Federal policy? Another question that might be raised is whether programs funded by the

Department of Education or those funded by the National Science Foundation are more effective in producing the desired outcomes in educational improvement.

The pending legislation would appear to provide a good base for launching a wide variety of educational improvements, including in education of the academically gifted in mathematics, science, and technology. Although the omnibus education bill now has been signed into law, the true test will come with funding of the programs. Making meaningful appropriations for these programs, during tight budget times, will serve as a reaffirmation of the commitment made in the legislation.

At budget time, legislators on appropriations committees may need to be reminded of the priorities set forth in the education legislation.

The Federal Government can provide the lead in setting educational priorities and can help assist State and local effort. These are necessary and appropriate roles for the Federal Government. How this lead is followed at the State and local level, becomes crucial in determining the improvement of particular programs, teachers, or students.

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Table 1

Percent of Annual Appropriation Allocated Among Recipients Under Current, Proposed, and Passed Mathematics and Science Education Legislation

	Current Law	S.373	H.R.5	Conference Language
I. Outlying Areas/ Indian Students	1%	1%	up to 1%	1%
II. Secretary's Discretionary Fund	9%	4%	5%	4%
III. State Allocation	90%	95%	at least 94%	95%
A. Ele & Sec Allocation	(63%)	(71.25%)	(84.6%)	(71.25%)
1. SEA	[18.9%]	[7.13%]	[9.4%]	[7.13%]
2. LEA	[44.1%]	[64.13%]	[75.2%]	[64.13%]
B. Higher Ed Allocation	(27%)	(23.75%)	(9.4%)	(23.75%)

Note. Percentages in parentheses indicate breakdown of State allocation. Bracketed percentages indicate breakdown of elementary and secondary allocation.

Table 2

Authorization and Appropriation Comparisons for Fiscal Year 1988

	FY 88 Auth	House FY 88 Appro	Senate FY 88 Appro	CR FY 88 Appro	FY 87 Appro	Net Change
Chap 2 Block Grants	Such Sums	$500	$500	$478.7	$500	-4.5%
Title II EESA	$350	$55	$150	$119.7	$80	+50%
Star Schools	--	--	$20	$19.1	--	--
NSF Sc/ Eng Ed	$150	$145	$115	$139.2	$98.9	+40%
NSF Research	$170	$1,505	$1,634.5	$1,453	$1,406.2	+3%
NSF Total	$1,893	$1,793	$1,866	$1,717	$1,623	+6%

Note. Figures represent millions of dollars and are rounded off to the nearest 1/10th.

FY88 Auth = Authorization for fiscal year 1988.
House FY88 Appro = House proposed appropriation for fiscal year 1988.
Senate FY88 Appro = Senate proposed appropriation for fiscal year 1988.
CR FY88 Appro = Appropriation passed in the continuing resolution.
FY87 Appro = Appropriation for fiscal year 1987.
Net Change = Change in appropriation between FY 1987 and FY 1988.
NSF FY88 authorization levels are those passed by the House only.

Source: H.J. Res. 395 Conference Report, House Report 100-498.

Table 3

Comparison of the President's Budget Request and Appropriations

	FY 86 Appro	FY 87 Appro	Pres FY 88 Request	FY 88 Appro	Pres FY 89 Request	Net Change
Chap 2 Block Grants	$478.4	$500	$500	$478.7	$540.5	+13%
Title II EESA	$52.1	$80	$80	$119.7	$119.7	0%
Star Schools	--	--	--	$19.1	--	-100%
NSF Sc/ End Ed	$53.2	$98.9	$115	$139.2	$156	+12.2%
NSF Research	$1,294.1	$1,406.2	$1,635	$1,453	$1,603	+10.3%
NSF Total	$1 457.4	$1,622.9	$1,893	$1,717	$2,050	+19.4%

Note. Figures represent millions of dollars and are rounded off to the nearest 1/10th.

FY86 Appro = Appropriation for fiscal year 1986.
FY87 Appro = Appropriation for fiscal year 1987.
Pres FY88 Request = President's FY88 budget request.
FY88 Appro = Appropriation for fiscal year 1988.
Pres FY89 Request = President's FY89 budget request.
Net Change = Change from FY88 appropriation to President's FY89 budget request.

Source: *Budget of the United States Government Fiscal Year 1988*
Budget of the United States Government Fiscal Year 1989

Discussant Reaction:
Encouraging Mathematics and Science Programs for the Gifted and Talented Student

Thomas R. Berger

Krista Stewart discussed the federal funding issue from the top down. I would like to look from the bottom up, taking Minnesota as my bottom starting point. I would also like to discuss what can be in place of what might be. Recommendations must be realistic and work within the present system.

Situation 1. Federal intrusion into education is generally not welcome.

Local school districts are rapidly responsive to voter sentiment which generally does not welcome federal intervention.

I discussed the Chapter 2 block grants with administrators in the Minnesota State Department of Education and with administrators in metropolitan and suburban Minneapolis and St. Paul. Uniformly, they all felt that the newer system of funding results in less paperwork and greater freedom to use the funds creatively. Less intrusion meant better education.

On the other hand, a St. Paul district mathematics consultant felt that without some guidance from the federal government, it was very difficult to obtain funds for either mathematics or gifted education.

Another administrator gave the following example: A district was doing well at the local level meeting a particular need covered by a special federal program. Because of this the district failed to receive funds from a federal program. With targeted special programs, districts may be penalized for having successful local programs.

All administrators felt that federal funds always helped encourage programs in the schools even when the funding was minimal. It is hard to pass up federal bucks.

Recommendation: Federal programs should not prescribe programs to the schools. Rather, there should be priorities placed on the uses of federal monies. A district can spend federal money on a lower federal priority if it is doing well on higher priorities. Gifted education in mathematics and science would be best served if it were set as a high priority in federal programs.

Situation 2. Viewed from the local level, federal monies have always been small compared to local expenditures.

For almost every American home owner school costs represent a significant fraction of every total tax dollar. It is unlikely that the fractions of funding for education from local, state, and federal sources will change significantly.

A typical large school district in Minnesota received about $250,000 from block grant funds last year. Title II demonstration grants averaged about $20,000 each over the past several years.

Some districts try to fold federal monies into their normal operating budgets, diminishing the significance of these funds. On the other hand, a suburban Twin Cities district set up a model program with $20,000 in federal funds. These funds paid part of a district gifted and talented coordinator's salary. This was the first such coordinator the district had. In following years, additional federal monies were combined with state funds to expand the gifted and talented program. As the program became established, federal funding was reduced so that the several coordinators will be supported totally through state and local funds next year.

These coordinators have increased awareness in the district for programs and activities in the schools for the gifted and talented. In particular, in mathematics and science, the district has asked for long range plans from each high school. The district has upgraded mathematics offerings in conjunction with its five year curriculum planning cycle.

The coordinators have increased awareness in academic extra curricular activities. For example, the district recently hosted a regional Odyssey of the Mind competition, and two of the three high schools qualified mathematics teams in the state mathematics league competition. These activities required additional extra curricular support. Federal funding therefore led indirectly to this increased support. This district still has a very low level dollar support for nonathletic extra curricular activities, but federal funds have caused some increases.

Recommendation: If small federal monies are to have much of an effect, they must be administered in a highly conspicuous and highly leveraged fashion.

Situation 3. Federal funds force short range planning.

Congress argues long and hard over its educational programs. The bills pass late and funds are appropriated (or not appropriated) in an untimely fashion. There is probably no cure for this situation.

Recommendation: Congress should make its priorities clear in advance. Federal agencies should receive administrative funds for these priorities the year before the actual program funds are appropriated. A full year administration and notification cycle should precede a funding cycle. School districts might not know how much money will be available but they will have advance notice of programs, priorities, and guidelines.

Situation 4. Grants are often episodic.

A grant is often made with the hope that a successful project will find local funding to continue. States send most of their funds to the schools. Higher education funds are for higher education, not teacher inservice. Legislatures must be taught the value of programs before they will fund them. Unfortunately, this all takes time.

Grants are seed money. The seeds are planted once and a perennial is supposed to grow. Unfortunately, the plant is more like an annual, after the grant runs out, the plant dies.

Recommendation: Good projects should be renewed three, four, or even five times, as long as progress is made toward a permanent outcome.

Situation 5. Teacher renewal projects often suffer from sputtering funding.

Through National Science Foundation grants many innovative teacher renewal programs are being developed. Requests for proposals often go out only a few months before the proposals must be written. It is difficult to write a good proposal in so short a time, especially for new writers.

Proposals must set time lines. For example, a summer project needs faculty, housing, speakers, and other activities. Often funds must be pledged six months before the program begins. Proposals are frequently not reviewed in a timely fashion. Grants are sometimes made in May for a July program. Because of this, some programs must be cancelled for the first summer delaying the program a full year.

Recommendation: Requests for proposals should be issued well in advance. Closing dates for submission should include time for a complete reviewing process and sufficient lead time to allow programs to start six months after the granting date. Such agency planning would be facilitated by a legislative two-year planning-implementing cycle.

Situation 6. Subject area specialists do not communicate with education specialists.

Since 1959 a whole new generation of scientists has come on the scene believing that research is the only true god. Federal research grants allow the funding of investigators, graduate students and visitors. Only those who actually contribute to the research will be funded.

It would be nice if some research grants could include university educators who are not contributors but are observers and learners. The inclusion of such people would force the investigators not only to advance knowledge, but also to clearly explain their investigations. Non-experts would have to understand the principles of the investigation.

Recommendation: Federal scientific research grants should encourage participation by knowledge area scientists by allowing 'educator learners' as fully funded participants in a research grant.

Recommendation: Federal education grants should encourage participation by knowledge area scientists by allowing 'specialist learners' as fully funded participants in both training and educational research grants.

Situation 7. Present mathematics textbooks are weak both in content and in presentation.

Mathematics textbooks have moved to rote computational skills, repetitive easy to grade homework, and emphasis on the simplest algorithms. The competitive textbook market makes all textbooks look alike in their awfulness. Publishers pander to the lowest common denominator.

Present innovations, such as the texts coming out of the University of Chicago School Mathematics Project, are viewed with skepticism by many teachers.

Recommendation: When evaluating any mathematics textbook, ignore chapter introductions, vignettes on famous people, and word problems. There must be a significant number of places in the remaining text where the student can read three English sentences in a row talking about mathematics. This non-mathematicsematical test eliminates almost all present algebra and geometry books.

Recommendation: Federal grants should encourage text writing activities, as they do now. However, federal programs should also encourage the widespread use of and modification of the newly developed materials. Only when the average level of texts improves will there be truly superb texts for the talented in mathematics and science.

Situation 8. Teacher subject knowledge in mathematics and science is currently very low.

While 70 years have been spent perfecting the educational environment, somehow knowledge has been left out. Teachers are highly trained in educational psychology and humane educational methods with less emphasis on knowledge areas. Many high school teachers of mathematics were 'C' level college mathematics students, completing much less than a full mathematics major. Many elementary teachers took no college mathematics courses at all.

Recent tests of teachers in the Twin Cities show that 25% of the fourth through sixth grade teachers cannot score above 50% on a test of simple division skills. One of every four students learns from a teacher who is deficient in mathematics. Administrators in Minnesota agree that the mathematics teachers are frequently not qualified but view replacement by mathematics specialists as a megabuck certification problem. On the other hand, they admit that each building does have a few people who like teaching and are pretty good at mathematics.

Recommendation: Federal programs in elementary schools should place a high priority on identifying good mathematics teachers irrespective of special certification as mathematics specialists. Maximum use should be made of present staff. The first step in the transition to mathematics specialists should not require certification or retraining programs. It is a problem of teacher identification and not certification. These knowledgeable teachers can be used most effectively to influence our best students in science and mathematics.

Recommendation: Teacher training grants made to colleges and universities should have the following priorities: greater emphasis on subject area knowledge; and greater cooperation between education departments and subject area departments. Where appropriate, grants should be administered through subject area departments or in cooperation between education and subject area departments. Only when physicists have some influence in teacher education will the physics teachers improve.

Situation 9. Except in extremely populated areas, the public schools cannot serve the exceptionally gifted and talented.

The University of Minnesota Talented Youth Mathematics Program (UMTYMP) has at most seven students from any high school. The only school sending this many is an inner city magnet school. Assuming that this program serves only 50% of exceptionally talented mathematics students, a four year school may have fourteen such students scattered over all four grades. It is not possible to form classes with three students. Even a district with four high schools probably could not justify a pullout problem.

Only a multidistrict pullout program (such as UMTYMP) or a special school (such as the North Carolina School of Science) can gather enough students to form adequate size classes. Because the cost of a special public residency school is very high and students must leave their homes, pullout programs might be preferable.

These pullout programs work. In Minnesota's first appearance last year at the American Regional Mathematics league national final, the state entered two teams which took third and sixth place in the 'B' division. These teams were dominated by UMTYMP students. Almost all high scorers on the American High School Mathematics Examination from the Twin Cities area are in the UMTYMP. The national winner in the Mathematics Counts competition a year ago was an UMTYMP student from Moorhead, Minnesota. UMTYMP students have been invited to study with the Olympiad team. UMTYMP students dominate the list of Twin Cities national merit finalists.

Recommendation: Federal programs should set as a highly priority special mathematics and science pullout programs which transcend school district boundaries. Federal school district funding should encourage cooperation between school districts and such pullout programs.

Situation 10. Americans have developed a very humane educational environment.

We have possibly the finest educational environment in the world. Parent satisfaction with schools is higher than in other countries, and student emotional problems do not seem to be as severe.

Recommendation: We do not want to alter, in a big way, the emotional environment created in our system of education. Gifted programs should continue the caring environment of our schools.

Discussant Reaction:
Current Federal Policy Regarding the Academically Talented In Mathematics, Science and Technology

George W. Tressel

If the flurry of the activity that Krista has discussed sounds bewildering, that's Washington. When someone says, "The sky is falling!" the classic Congressional role is to listen and deliberate. Then, if appropriately impressed, they provide some general ground rules and resources, and they settle back in the hope that someone will figure out the details.

This is all that we should expect from a legislative body, but it also is part of the reason for the hot and cold running water syndrome that we have seen in science education. The last time, Congress responded because "The Russians were coming!" Now we're doing it again because "The Japanese are coming!" Neither is a particularly good reason to turn the faucet on, but it is fortunate that science education is getting attention; and considering the complexity of the problems, it's remarkable that Congress does such a good job.

As long as Congress continues to do its part--providing the resources--it becomes our problem to warrant this support, and to provide some of the stability that Dr. Stewart was talking about.

Many years ago I drew a moral that stays with me today. For a couple of years, I worked on the atomic airplane project: a waste of roughly a billion dollars of your money. In the end I resigned because I felt that it was an unethical and unconscionable waste. Ten thousand people worked on the project; yet I never found anyone besides myself who had such qualms. Nor in the years since, when I see my old colleagues, have I found any doubt that it was in the national interest.

The moral I draw from this is that it is almost impossible for people to engage in critical self evaluation when a serious self interest is involved. We all look at life through a strong filter of self interest. Since all of us here are from the academic and research communities, that is *our* filter of self interest. I'd like to pose an alternative--a view with a bit less emphasis on our quest for knowledge and research support.

We all agree on the need for more knowledge, and we certainly should be doing more research, and we certainly need to find more ways to apply our knowledge. BUT . . . Congress is not sending over a hundred million dollars a year because they think this is an academic question. They are persuaded that the U.S. faces serious problems, both in economic and technological competition with other countries and in the skills and knowledge of our next generation.

Congress is sending money because they want something *done* about this. And knowledge and research are only good in so far as they help.

As we all know, education presents an enormous *system* problem. This system, with its diffuse authority, low status and enormous inertia, has deteriorated noticeably and must be repaired. How do we do that? Rhetoric about support for gifted and talented is common, but I don't hear a central philosophy or perspective. It just seems like a good idea; who could argue against help for the gifted and talented?

There are some important tradeoffs that should be weighed--between the chaos of neglect and the smothering embrace of a "Federal Curriculum," which no one wants or would accept. Perhaps the populist control, and the flexibility of our system is the reason that it has done so well over time, despite its clear weaknesses.

Let me describe the system a bit, and some of the concerns that we see at NSF. The 16,000 independent school systems--largely held together by little more than the College entrance requirements--present a reality that we must work with. Consider the "envelope" of flow throughout the system.

Most of the population completes elementary school, but by the time you reach the end of four years of high school, roughly twenty-five percent has dropped out. Only seventy-five percent completes high school. Roughly fifty percent goes on to college and roughly twenty-five percent completes four years. Then the flow drops to about five percent that enters graduate school--and after further attrition, this "tail" becomes the "intellectual resources" of the country.

Within this envelope, what do we do about science education? To begin with, the process has split the population in two halves. We tend to forget that half the population does not make it past high school. The other half, by and large, has four years of college or less. That is why newspaper ads specify "college graduate" or not: they usually aren't seeking a particular skill; they are specifying a person from one or the other half of the population.

What do these two portions learn about science and technology? In elementary school, for all practical purposes, in most schools most of the time for most children, *there is no science.* Science starts at the age of fourteen when someone takes a kid who, by and large, has no background, no preparation--except what they learned informally from parents, books, museums, hobbies, etc.--and asks whether this unprepared youth would like to take things like Botany, Zoology, Chemistry and Physics.

Usually the answer is "No." Twenty-three percent of the population takes enough to be considered meaningful (three years of mathematics/science) and even for this portion, it is not for career interest; it is to get into college. Less than one in five who take these courses do so because they are interested in mathematics or science as a subject or as a preprofessional topic.

The motive is then played out when they do get to college. Roughly five percent takes mathematics/science/engineering and that drops to roughly half by the end of four years; and less than one percent goes on to graduate study. This then, is the source of our technical infrastructure. Do you think that the process is systematically preparing, encouraging and selecting our best prospects from every part of the population? Do you think that most of our potential talent is being nurtured and prepared for an education and role that will develop its potential? I don't.

Given this flow pattern, do you think that we can solve our need for more scientists and engineers by recruiting more at the undergraduate level? When we're already taking more than one out of five of the twenty-three percent who are "prepared." Maybe we can, and I wish us luck because we're going to try. And we're probably going to lower standards in order to do so.

The truth is that if we really want to do something about this, we must address the demographics of our country, and find the people who traditionally say no to the question of whether to take science or mathematics when they are fourteen years old. The ones who say no traditionally fit into two categories: women and minorities. We can't afford that, and we've got to do something about it. We have to change the pattern.

We can of course, try to recruit more at every stage. But the trouble with our system right now--if there is a single core problem--is probably that we rely almost entirely on this approach: a system of *testing and selecting,* instead of *cultivating and teaching.* As long as we have this pattern, nothing much will change.

That is why we in NSF's curriculum programs are focusing our highest priority at the elementary school years, where there is still time to change the course of events. Our efforts are directed toward building a broad spectrum of talent, not just the next Nobel Prize winners. Not just "scientists," but also engineers, technologists and support cadres. We need a full technological infrastructure and managers and decision makers who understand enough science to carry on an intelligent conversation with an "expert."

Where then do the gifted and talented fit in this pattern? To review, we need three kinds of people:

1. An educated populace that can read about science and technology in the newspaper,
2. Managerial and decision-making cadres that can converse with and weigh the views of scientists and engineers,
3. The science and technology infrastructure.

Leading this technological pyramid must be the gifted and talented. How do we provide this?

First, we must establish a base-line science education for all students in both science and mathematics. This should be co-equal in priority with language and cultural arts; science is the humanities of our time.

This base-line mathematics/science curriculum should serve as a strong preparation for preprofessional courses, in chemistry, physics and so on. It should also provide a universal overview in preparation for college science. And it should provide a science literacy for the fifty percent of students who are going to stop at the end of high school.

Second, we must upgrade the level and standards of our disciplinary courses in keeping with the ever more demanding content and standards of preprofessional preparation.

Finally, we should parallel this higher standard of disciplinary curriculum with special programs for the gifted and talented: programs like TIP and SMPY. In this ideal system, every child would get a base-line preparation. Those intent on a career would study with others who have the same motivation and preparation. And for every student that shows exceptional talent and promise there would be a program of cultivation and encouragement.

Whatever the level of ability, skill and motivation, there should be a program of encouragement and challenge. And that includes the "severely gifted."

That's easier said than done, of course, but we at the National Science Foundation are determined and trying to provide a catalyst. There are significant trade-offs between the roles of different agents--even in the government. Dr. Stewart mentioned the differences between NSF and the Department of Education; the two agencies have complementary but very different strengths. NSF is closely linked to the academic community; we have many links to research workers, developers and so forth. And we're learning to work closely with school systems and educational marketers.

At this time, we have eight "troika" projects that combine academics, school systems and publishers, all working together as a team. All but one are at the K-6 level; this year we expect to start a number of middle school projects, and next year we will make a half dozen of the same genre for high school. Together, they will establish a number of coherent K-12 base-line science alternatives. Meanwhile, we're also working on improving the mathematics curriculum to focus more on problem solving, computers and contemporary applications.

So, NSF is especially good at research and development. But we are neither well experienced nor well equipped to work at the local level with SEA's and LEA's. Nor should we be. These are areas that require large scale funding and direct local involvement. They are much better suited to the nature, funding, style and experience of the Department of Education.

Recognizing this, I can't close without mentioning the primary weakness in the development strategy that I've been desribing: *implementation.*

In a few years, these publishers will offer a half dozen alternative science curricula to school systems. The most frustating thing would be if systems were not prepared or funded to by the materials and the teacher training programs to accompany them. It is not going to be easy, and it is the border where responsibility transfers from NSF to state and local decision makers.

We need their help and we hope that our efforts will serve their needs. Our schools need large and difficult changes. We need to change the teachers' roles. We must provide more time for teachers to plan, more support staff so that teachers can be more professional and focus their attention on their real job, and better facilities to do the hands-on, experietial learning that all of us endorse. We at NSF hope that our efforts contribute to this picture.

CREATING SCHOLAR/PRACTITIONER NETWORKS FOR THE MOST CAPABLE YOUTH IN MATHEMATICS, SCIENCE AND TECHNOLOGY

Don I. Phillips

How can the results of research--in fields such as education, psychology, sociology, anthropology, and economics--serve to improve the practice of education? This question is of long-standing concern to the educational community, both scholar/researchers and teacher/practitioners. One solution often proposed is to establish more effective means for ongoing communication and greater mutual understanding between these two communities. My own direct experience with this topic is limited to a year I spent as an education policy fellow at the National Institute of Education over ten years ago--hardly a basis for my providing any enlightenment on the subject to the knowledgeable and experienced group gathered at this conference. What I have been doing for much of the past ten years is establishing procedures and institutions for collaboration, in both the conduct of research and the formulation of science and technology policy, among working scientists and engineers in universities and industry, academic administrators, industry officials, and federal and state program managers and policy officials. I assume, therefore, that the organizers of this conference felt that my experience with these types of networks would provide a basis for discussion of what would work best in creating scholar/practitioner networks to focus on issues related to the most capable youth in mathematics, science, and technology. I hope I can fulfill their expectations.

Other speakers will address problems in the identification, education, and nurturing of the most talented students and describe research pursuits that might help the practitioner community in carrying out these functions more effectively. I take my task to be the identification of operational and organizational principles that should guide the establishment of networks to facilitate ongoing interactions between the practitioner and scholar communities in defining the problems that need attention, in carrying out the research on the problems, and in incorporating the results of the research into educational and support programs for the most capable youth.

First, however, I will address one topic in the area of science and engineering talent that requires further examination and research. Then I will return to the topic of scholar/practitioner networks.

Nurturing Science and Engineering Talent

The Government-University-Industry Research Roundtable has identified the development, identification, recruitment, and retention of science and engineering talent as the most critical issue facing the scientific enterprise. Recently the Roundtable, along with other units in the Academy Complex, has been examining the adequacy of the flow of the most talented students into graduate school in the sciences, mathematics, and engineering. I will review the findings and areas for further study identified in this investigation since they seem most closely related to the topic of this conference.

While the main focus of the investigation was on the junction between undergraduate and graduate school, I will begin with a review of student choices of undergraduate major because decisions at this stage affect the ultimate flow of students into graduate school.

Using data from the Cooperative Institutional Research Program (CIRP) Solmon looked at:[2]

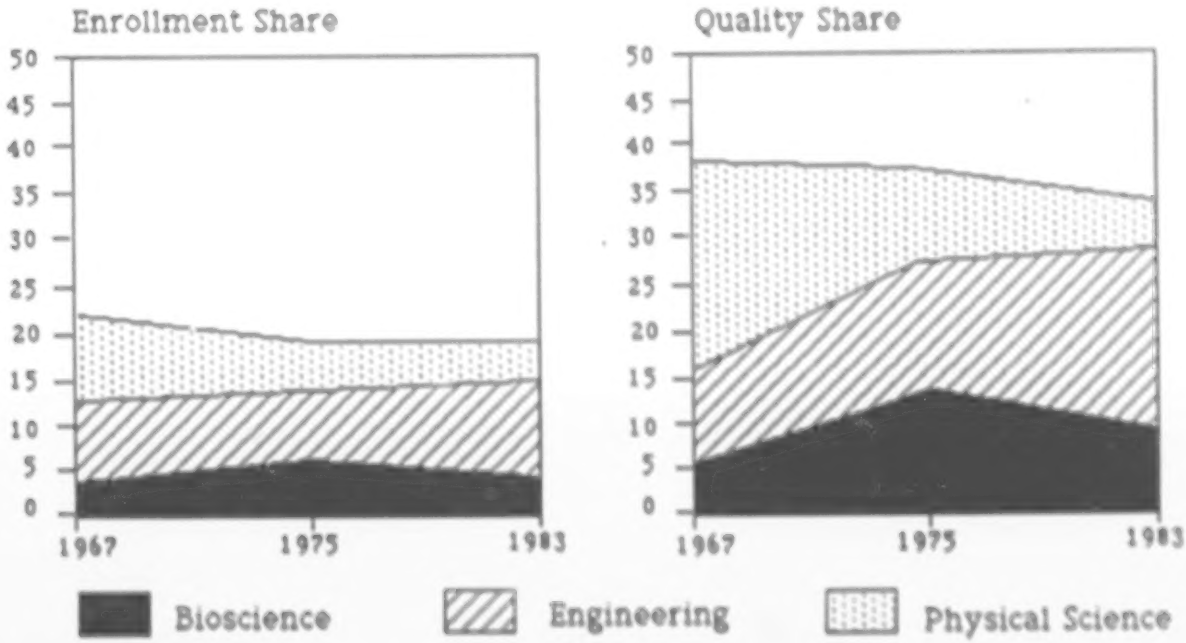
- The change in the share of all freshmen intending to major in a particular field. He calls this the "Enrollment Share" (ES).
- The change in the share of "smart" freshmen intending to major in various fields. He calls this the "Quality Share" (QS). A very restrictive definition of smart was used: 1) A/A+ high school average, 2) accepted to all schools to which they applied, 3) aspirations to more than a bachelor's degree *and* 4) expectations of graduating with honors.

Between 1967 and 1985, the shares of all students and smart students intending to major in science and engineering changed as shown below in Figure 1. The data are included in Attachment I.

At the undergraduate level, science, mathematics, and engineering combined continue to have a strong attraction for the very bright students. There have been shifts, however, among the fields. In the biological sciences both enrollment and quality went up temporarily and returned to near former levels. Engineering is attracting more and better students, and the quality share increased even faster than the enrollment share. The quality share and enrollment share in the physical sciences maintain about the same ratio, but the sharp decline in interest in the physical sciences means that fewer smart students are entering this field.

Figure 1

Choices of Undergraduate Major 1967-1983



In Attachment II data compiled by Holstrom are summarized which add to Solomon's findings that significant proportions of the brightest students continue to major in mathematics, science, and engineering at the undergraduate level. Three sets of data are included in the attachment: 1) the change between 1981 and 1985 in the percent of freshmen intending to major in various science and engineering disciplines who had A+/A/A- high school grade average, 2) the percent of students who graduated in various science and engineering majors who were top students (those in the 1981 freshman cohort who earned B+ or better averages in 1985), and 3) persistence rates by field and field switching patterns of students with A averages at the time of receipt of the bachelor's degree.

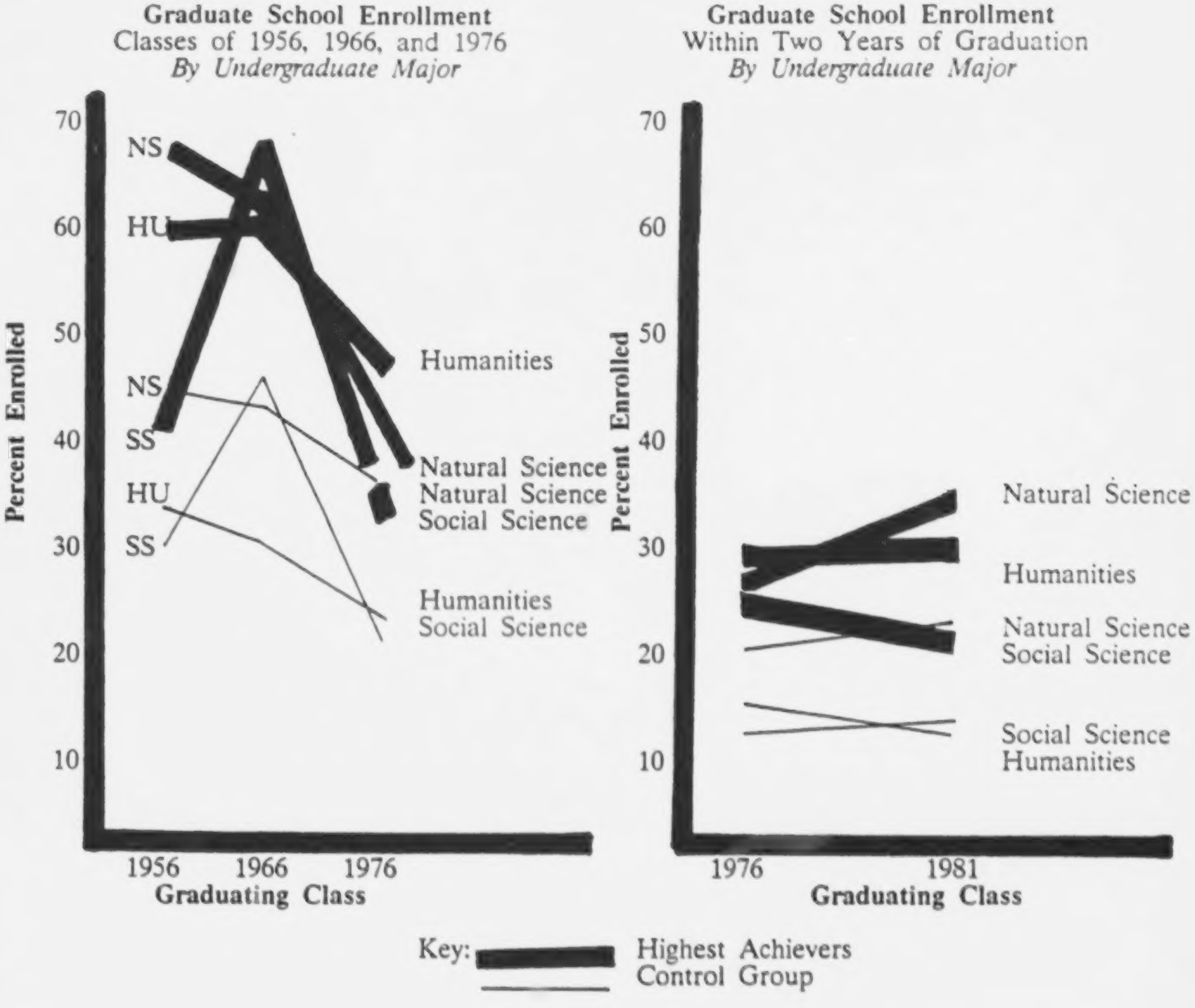
At the graduate level, the data are limited; we could find only three relevant studies.

- Figure 2 summarizes the findings by Goldberg and Koenigsknecht[3] in their study of the post-baccalaureate enrollment of the "highest achievers," i.e., students among the top 3% to 5% of their graduating classes of the COFHE (Consortium on Financing Higher Education) institutions--eleven private and three public institutions. The figure shows that between 1966 and 1976, the highest achieving undergraduates increasingly chose professional school over graduate school and that there was a sharp decline in the highest achievers in the natural sciences going on to graduate school. Between 1976 and 1981, the proportions were level or increased slightly.

- Hartnett had looked at the SAT and ACT scores of people who earned doctorate and professional degrees between 1966 and 1981. Figure 3 shows that the proportion that scored 750 or higher on the SAT mathematics test rose in each of the four science fields. This study asks: of all students who received Ph.D. degrees, what proportion were high achievers in high school? Thus, we do not get a sense of the fraction of the superior students who never went on to graduate school in the sciences.

- Table 1 shows the GRE scores of students planning to enter graduate programs in the sciences, mathematics and engineering. ETS does not have data prior to 1980 so unfortunately only recent data points are possible. The data show that while the absolute number of top scores is up in every field, the increases in the biological and physical sciences are not as high as the overall increases in the number of top scores. Thus, the share of top scorers attracted to these fields is down. Conversely, in the mathematical and engineering sciences the increases in the number of top scores are above the general rate, giving those fields increased shares.

Figure 2



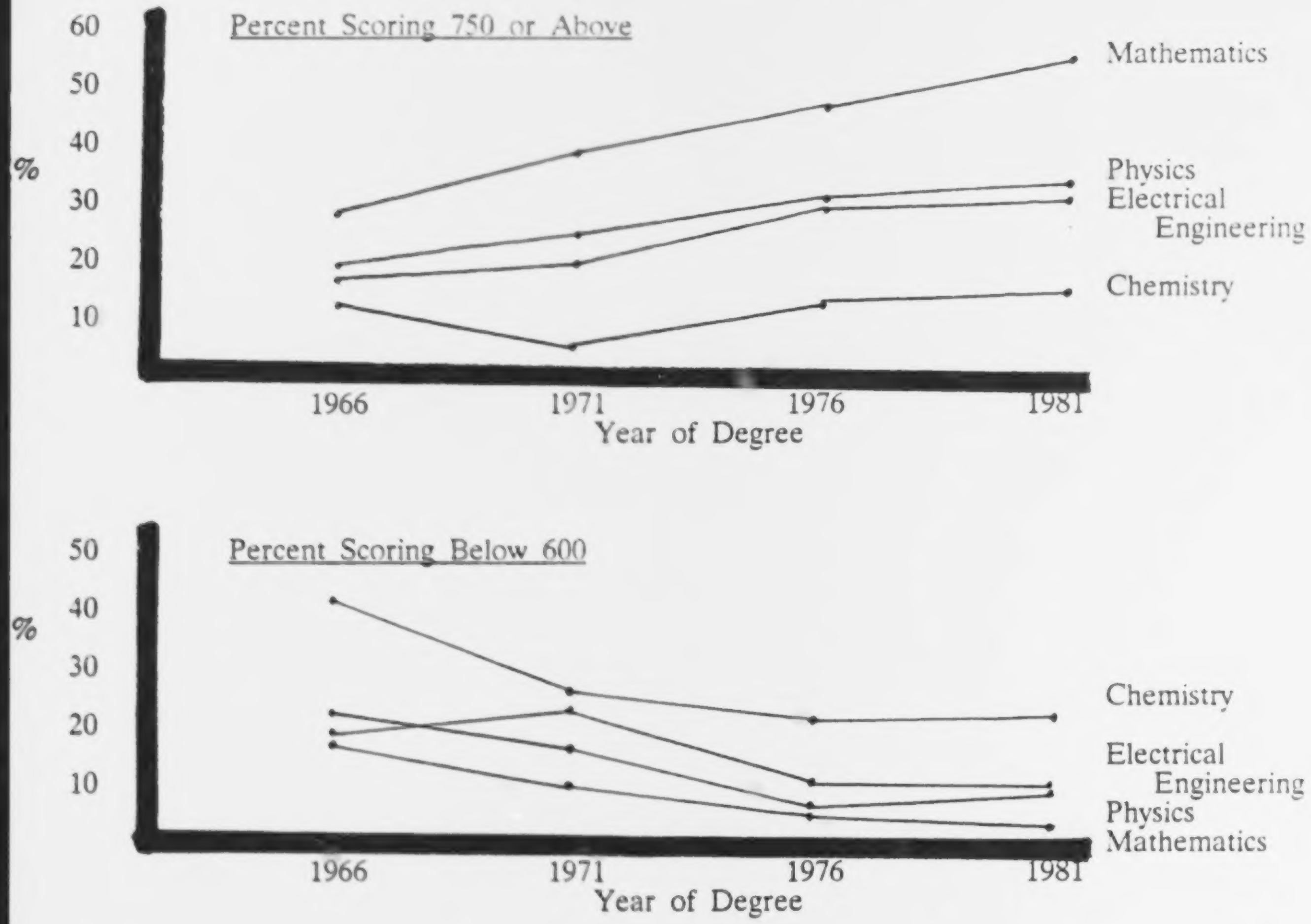
Graduate School Enrollment
Classes of 1956, 1966, and 1976
By Undergraduate Major

Graduate School Enrollment
Within Two Years of Graduation
By Undergraduate Major

Source: Goldberg and Koenigsknecht. **Highest Achievers**. Northwestern University, 1985.

Figure 3

Percentage of Science Ph.D.'s Scoring Above 750 (Top) and Below 600 (Bottom) on the SAT-M, by Year of Doctorate



N for SAT-M

	1966	1971	1976	1981
Math	53	129	125	87
Physics	124	226	238	212
Electrical Engineering	49	110	96	94
Chemistry	163	355	373	...

Source: Hartnett, Rodney T., "Has There Been a Graduate Student 'Brain Drain' in the Arts and Sciences?"

TABLE 1
TABULATIONS OF ETS DATA ON GRE SCORES/TEST-TAKERS

	Quantitative		Percent change	Verbal	
	1981/82	**1986/87**		**1981/82**	**1986/87**
All U.S. Citizen GRE Test-Takers	157,810	180,866	+15%	157,810	180,866
Number scoring 750+ (top scorers)	6,057	10,630	+75%	2,705	3,518
Percent of top scorers	3.8%	5.9%	-	1.7%	1.9%
Physical, Biological Mathematical and Engineering (PBM&E) Sciences					
Total Number of test takers expecting to enroll in PBM&E	30,087	36,010	+20%	30,087	36,010
Number of PBM&E test takers with top scores	3,900	6,891	+77	643	786
PBM&E top scorers as percent of all PBM&E test-takers	13.0%	19.1%	-	2.1%	2.2%
PBM&E top scorers as share of all top scorers	64.4%	64.8%	-	23.8%	22.3%
Physical Sciences (PS)					
Number of test takers	6,930	6,265	-10%	-	-
Mean GRE score	623.5	641.5	-	-	-
Number scoring 750+	844	1,151	+36%	-	-
PS top scorers as percent of all PS	12.2%	18.4%	-	-	-
PS top scorers as share of all top scorers	13.9%	10.8%	-	-	-

		QUANTITATIVE	
	1981/82	1986/87	Percent change
Biological Sciences (BS)			
Number of test takers	9,167	8,327	-9%
Mean GRE score	572.2	575.9	-
Number scoring 750+	345	514	+49%
BS top scorers as percent of all BS	3.8%	6.2%	-
BS top scorers as share of all top scorers	5.7%	4.8%	-
Mathematical Sciences (MS)			
Number of test takers	5,921	8,853	+50%
Mean GRE score	646.8	657	-
Number scoring 750+	1,101	2,021	+84%
MS top scorers as percent of all Mathematics	18.6%	22.8%	-
MS top scorers as share of all top scorers	18.2%	19.0%	-
Engineering Sciences (ES)			
Number of test takers	8,069	12,565	+56%
Mean GRE score	668.6	676.4	-
Number scoring 750+	1,610	3,205	+99%
ES top scorers as percent of all ES	20.0%	25.5%	-
ES top scorers as share of all top scorers	26.6%	30.2%	-

Source: Government-University-Industry Research Roundtable, unpublished working papers.

The data provide only a limited understanding of the adequacy of the flow of top students into science, mathematics, and engineering graduate programs. While the results of these studies do not demonstrate the existence of a problem, neither do they provide a sufficient basis for feeling sanguine about the situation. Anecdotal evidence in the form of testimony by university faculty points to signs of trouble, and there are additional causes for concern.

- The declining interest of top U. S. undergraduates in the physical sciences is worrisome.

- The movement of top students from the physical sciences to engineering is part of the more general movement of students toward utilitarian degrees. However, there are deeper implications here than simple field preference because, although engineering education is more "scientific" than it used to be, engineering students are less likely to go on to graduate school than those in the physical sciences. This has potential impact on the quality of the research work force.

- Demographic trends are well known and disturbing. The number of twenty-two year olds is projected to drop more than 25 percent before the end of this century, and already fewer U. S. students with bachelors degrees in the natural sciences and engineering are electing to continue on for Ph.Ds. Increased female and minority participation could raise overall degree attainment rates, but achieving this at a significant level will be difficult.

- Major losses to the science and engineering talent pool occur during the college years and in the transition from undergraduate to graduate school. By college graduation, only 35 percent of the high school seniors who planned on mathematics, science, and engineering majors have stayed with their plans. Over 80 percent of mathematics, science, and engineering baccalaureates have never started or have left graduate school within three years of college graduation. The scientific community has long assumed that the students with the best scientific minds generally will pursue science as a career; that they will be disproportionately represented among those who persist through college and graduate school, and that their passion for science will override any disincentives through such factors as the availability of jobs, income potential, job security, and occupational status. There is reason to believe now, however, that the best students are influenced by the same economic incentives and the same push and pull of opportunity that moderate the flow of scientific talent generally; that is, that the stability and level of support for research projects and the comparative value of salaries, for example, will attract or discourage the smartest students right along with the merely good ones.

Scientific breakthroughs and technological advance depend on the work of the brightest and most creative minds. Yet we know little about the flow of these students into research training programs and about the factors that influence their decisions. The impact of demographics on supply alone indicates that the competition among government, industry, and universities for these most talented students will become increasingly intense over the next decades, and that the time, effort, and money required to attract, nurture, and retain an adequate share in science and engineering talent, as some predict, will exacerbate the challenges. To be successful in this competition, we need to know more about this cadre of college students than we do currently. This is a topic for further research and an area in which the research findings need to be incorporated into educational practice.

The Roundtable will continue to work in this area; I am interested in your suggestions of important questions to investigate. The work will involve a mix of scholars, college faculty and administrators, policy-makers, and students. This is typical of the cross-section of people that participate in Roundtable activities, and therefore our structure and operating procedures are relevant to the creation of scholar/practitioner networks.

The Government-University-Industry Research Roundtable

The Government-University-Industry Research Roundtable (GUIRR) was established in 1984 as an alternative to the traditional study commission approach to science and technology policy issues. It is sponsored by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. Two unique features characterize the Roundtable.

First, the Roundtable was created on the assumption that all sectors--government, universities, and industry--share the responsibility for the stewardship of the scientific and engineering enterprise and for ensuring its continued contributions to the national well-being. Both the structure and the operation of the Roundtable are based on this premise. The Roundtable Council, the guiding body for the organization, includes senior federal R & D officials, senior officials from academia and industry, and working academic scientists and engineers. The members of the Council are listed in Attachment III.

The second unique feature of the Roundtable is its ongoing nature. It is not a group convened to study an issue, write a report, disband and go home. The Roundtable is a means for addressing the important issues within a structure that provides for continuity and follow-up. This is the first time that all the parties have sat down together in an organized manner and on a continuing basis to examine the critical problems and opportunities facing American science and engineering.

The purpose of the Roundtable is to try to understand issues, to inject imaginative thought into the system, and to provide a setting for the seeking of common ground. The Roundtable is a forum in which all the parties work together through the Council to define an agenda and to examine the topics selected. The Roundtable is not an organizational unit that outside groups commission to undertake specific studies nor is the Roundtable a group that designs studies for specific clients.

The initial results of this experiment of a new approach to science and technology policy issues are encouraging. The Roundtable has established a tradition for convening principals from all sectors on a regular basis, and it is recognized by agencies and organizations of federal and state governments, universities, and industry as being effective in stimulating new ideas and actions within the R&D enterprise. Furthermore, assuming there is credence to the adage, "imitation is the highest form of flattery," it is noteworthy that the Roundtable has served as a model for the design of three similar organizations within the Academy Complex to address three different areas--the Manufacturing Forum, the Forum on Drug Development and Regulation, and the National Forum on the Future of Children and Their Families.

Several features of the Roundtable structure and operation have been essential to its initial success. They are summarized below:

1. *Sponsorship.* The sponsorship of the Roundtable by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine provides a natural setting with credibility among all elements of the research community in the three sectors.

2. *Roundtable Council.* The senior federal R&D officials and top industry officers are full and active participants on the Council. Their contributions and leadership have been essential to the accomplishments of the Roundtable.

3. *Working Groups.* The Research Roundtable identifies and examines issues through working groups. Once the groups have elucidated the central issues for the topics selected, identified the problems and opportunities, and considered options for dealing with them, they bring their observations and conclusions back to the Council for further discussion. This combination of study and analysis in the working groups by operational-level representatives from all sectors and discussion in the Council by policy-level representatives from all sectors has produced an environment that leads to the introduction of new ideas and new procedures into the system.

4. *Balanced Views.* The Roundtable has established a reputation for working effectively with all sectors while maintaining neutrality and objectivity. All points of view are presented in Roundtable deliberations. The Roundtable has avoided becoming a proponent for the views of any one constituency. The focus of Roundtable deliberations has been: what is best for the national interest?

5. *Long-term vs. Short-term Issues.* The Roundtable has achieved a workable balance between the attention to broad, ongoing concerns of the research community (for example, nurturing science and engineering talent, financing the university infrastructure, and enchancing university-industry interactions) and to the search for solutions to immediate problems (for example, streamlining administrative procedures for government-sponsored university research and for industry-sponsored university research, assessing the effectiveness of state government science and technology programs, and operating multidisciplinary research and education programs in universities).

6. *Flexible Financial Support.* Support for the Roundtable has been provided by the National Research Council; the Sloan and Mellon Foundations; the Departments of Agriculture, Defense, and Energy; the National Institutes of Health;

the National Science Foundation; the Monsanto Company; and the Pennsylvania Ben Franklin Partnership Program. The majority of these funds is provided as general support for the Roundtable, enabling the Roundtable to respond quickly to problems and opportunities as they arise and to address issues in flexible, diverse, and innovative ways.

7. *Personalities.* The Roundtable is foremost a process--a process for bringing together the diverse constituencies concerned with the research enterprise for common purpose. As such, it is an intensely personal enterprise, whose effectiveness has depended on the ability of Dale Corson, the first Roundtable chairman, James Ebert, the current Roundtable chairman, the Council, the working groups, and the staff to work constructively together and with the full range of relevant constituency groups and individuals. The ability of the Roundtable to stimulate constructive change in the system depends on the "delicacy" and the balance with which it is able to address issues that are typically complex, intractable, emotional, and controversial.

Additional Examples of Scholar/Practitioner Networks

I have selected five additional scholar/practitioner networks for consideration: two are national networks outside the field of education; one is a national network within education, and two are education networks at the local level. I conclude by proposing for discussion a list of principles for establishing and operating scholar/practitioner networks based on these examples and on the description of the Government-University-Industry Research Roundtable.

Before turning to the examples, it is helpful to consider the question, "What are the obstacles to scholar/practitioner networks, both generally and within the field of education?" The answers to this question are useful guides to identifying the essential characteristics of successful networks. Within any field of endeavor, scholars and practitioners have difficulty working together because of differences in intellectual milieu, values, reward systems, goals and objectives, and time scale. Successful networks find procedures, organizational structures, and operating personnel to minimize these differences.

Turning to the field of education in particular, we note sharp contrasts between scholars, principally in universities, and practitioners, principally in K-12 education, in the following areas: the prestige attributed to teachers at each level; the power of teachers as compared to administrators within each setting; the extent to which a scholar and a practitioner are considered as a contributor to the knowledge of a subject; how well it is thought a subject must be mastered by a scholar and by a practitioner. Scholars tend not to respect teachers and do not consider them as full-fledged members of their disciplinary professional societies. In addition, teachers tend to be isolated, have inadequate opportunities to renew their professional knowledge, have a limited role in developing curricula and school policies and practices, are skeptical of the relevance of scholarly activity and of the sincerity of scholars to the everyday challenges they face, and are disillusioned by the unsuccessful, on-again off-again efforts of the past aimed at improving school practices and linking the school community with the scholarly community. One teacher has commented, "Teachers are used to seeing something go for one year and then dropped. I've been in four or five of those projects myself and it is a disaster [when they are cancelled]." Overcoming these obstacles is difficult. As some of the examples below illustrate, however, it can be done.

Agricultural Research System and Extension Service. The venerable and perhaps over-used example of an effective scholar/practitioner network is the agricultural research system and extension service. The central features of the system include:

- A national and regional research system financed principally by the federal government with research priorities focused on national and regional problems.
- A state-centered research system financed by state and federal governments, with the states being the larger funder, and with research priorities established principally to focus on state and local problems with substantial input into these priorities from state and local agricultural practitioners.
- A local county-based extension service to serve as a linkage between the state, regional, and national research enterprise and the local farmer. These county agents are the linchpin in bridging the scholarly and practitioner cultures in agriculture.

While there is plenty of criticism of the agricultural system as it struggles to adjust to current times, its overall success is unquestioned. What is questioned is the relevance of the agricultural research system and extension service to the educational system. The agricultural system is designed to meet the needs of the individual farmer. The farmer in turn has an economic incentive to learn of the latest scientific advances and has control over whether and how he uses this knowledge. In education, it is not sufficient to share new knowledge and demonstrate new practices with a teacher. The teacher is imbedded in a system of complex layered organizations that must be mobilized if new practices are to be implemented. In addition, other than personal motivation the teacher has had minimal if any incentives to pursue change in educational practice; there are attempts to change this situation now.

Transportation Research Board. The Transportation Research Board (TRB) is a unit of the National Research Council, which is the operating arm of the National Academy of Sciences and the National Academy of Engineering. The predecessors to TRB were established in 1920, TRB was established in 1974 with the purpose to advance knowledge concerning the nature and performance of transportation systems by stimulating research and disseminating the information derived therefrom. TRB is sponsored by the state highway or transportation departments, the Federal Highway Administration, the Federal Aviation Administration, the Urban Mass Transportation Administration, and the Association of American Railroads. About 35 percent of its support comes from the state highway and transportation departments; about 39 percent comes from federal government agencies; and the remainder comes from other associations, publication sales, etc. Through a broad range of technical activities, meetings, publications, and field visits, all of which are interrelated through an organizational structure operated by the TRB, there is a high level of communication, research priority setting, research program operation, and sharing of research results among local, state and federal transportation practitioners and the transportation research community. TRB is recognized as the agency that reports the useful results from the nation's transportation research, and it is also a focal point for convening the practitioner community. Productive interaction between the two communities is the result.

The Mathematical Sciences Education Board. The concept of the Mathematical Sciences Education Board (MSEB) was brought to the National Research Council by the mathematics community. In part, it is modeled after the Transportation Research Board--a focal point at the national level for linkage among researchers, practitioners, administrators, and policy-makers, for the development of programs, practices and policies that must be implemented at the state and local levels.

In 1985, the National Research Council established the Mathematical Sciences Education Board. This Board is designed to become the most comprehensive and far-reaching national leadership effort in mathematics education ever to be undertaken in the U. S. The goal is a systematic, nationwide, transformation of school mathematics. MSEB is still relatively young, but let me review some of its central features:

- The Board has representatives of all the stake-holders in the educational enterprise, including state government officials, school teachers and administrators, representatives from school boards, the PTA, both the mathematics education and the mathematics research organizations, and senior officers from some of the nation's leading companies. Professors and administrators from the country's most prestigious universities sit on the Board alongside teachers who face children in the classroom every day.

- MSEB will engage teachers, state and local education agencies, together with research mathematicians and officials from industry in processes of discussion, coordination, and the development of complimentary projects. The output of MSEB will not be pronouncements from "on high," but will be statements of common understanding among these communities.

- The MSEB is developing a working relationship with the National Center for Research in Mathematical Sciences Education at the University of Wisconsin and through this relationship will provide a linkage between the research and practitioner communities. MSEB also has an ongoing working relationship with the National Council of Teachers of Mathematics, as well as with the major organizations of research mathematicians.

Ford Foundation Urban Mathematics Collaboratives. In 1985, the Ford Foundation launched an experimental program to strengthen mathematics education in inner-city high schools. The Foundation has established eleven math collaboratives. The collaboratives will receive Foundation support for three to five years before becoming completely self-sustaining programs.

An urban mathematics collaborative typically consists of a community advisory board that includes teachers, school administrators, and leaders from business and higher education; a series of subcommittees that oversee specific collaborative functions; and a part-time administrative staff. The goal is to involve virtually all of the city's high school mathematics teachers in a diverse set of school-year and summer activities, jointly designed and operated by teachers and mathematicians from educational, cultural, and business institutions. Specific collaborative activities include industrial internships, exchange programs with colleges and industries, evening symposia, newsletters, and summer workshops. By fostering colleagueship among mathematicians from all sectors and increasing the human and financial resources available to teachers, the projects seek to reduce teachers' isolation, to boost their professional enthusiasm, to enhance both their receptivity to new ideas and their capacity to discriminate among them, and to encourage resourcefulness in their teaching. Central features of the program include:

- External support from a leading foundation to catalyze the program and mobilize a broad coalition of community resources.
- An ongoing programmatic focal point was created. The Education Development Center in Newton, Massachusetts, serves as an information and resources center to provide the collaboratives with information about mathematics and mathematics education, help them plan and implement their individual programs, and facilitate communication among the various projects.
- Each of the eleven projects is different, and builds on local strengths, local prestigious institutions, local influential individuals, and involves local financial resources.
- The local collaboratives project a sense of continuity; teachers are developing confidence that the collaborative is "here to stay."
- Summer institutes, mini-grant programs for innovative projects, and teacher resource centers all are structured to increase the professional self-esteem and horizons of the participating math teachers. Linkages with practicing mathematicians and research mathematicians are a part of these activities.
- Teacher advisory boards are an effective approach to placing teachers in leadership roles within the collaboratives.

The Yale-New Haven Teachers Institute. The Yale-New Haven Teachers Institute was established in 1978 as a joint program of Yale University and the New Haven public schools. Each year about eighty New Haven school teachers become fellows of the Institute to participate in seminars with Yale Faculty members. The seminars have two related, and equally important, purposes: general study of the seminar subject, and research and writing on individual curriculum units. In this way, curriculum development is integrated with intellectual renewal for teachers.

Four principles guide the program and constitute much of its distinctiveness: 1) the belief in the fundamental importance of the classroom teacher and of teacher-developed materials for effective learning; 2) the insistence that teachers of students at different levels interact as colleagues, addressing the common problems of teaching their disciplines; 3) the conviction that any effort to improve teaching must be teacher-centered and the consequent dependence on the Institute coordinators, who are teachers in each school, who meet weekly with the director and who constitute an essential part of the program's leadership; and 4) certainty that the university can assist in improving the public schools only if it makes a significant and long-term commitment to do so.

Important features of the program include:

- It is a sharply focused effort with a well-defined approach confined to the public schools in New Haven.

- There is intellectual symmetry in the program; university faculty provide the major competence and initiatives in the area of subject matter and the follows drawn from the faculties of the New Haven middle schools and secondary schools provide the major competence and initiatives in the area of pedagogy. Topics for the seminars are generated by the secondary school teachers; content of the seminars is drawn from the university professors.

- There is unqualified commitment to the program by the New Haven public schools and by the top administration at Yale; this commitment has been enduring and all indications are that it will be for the long term--Yale has decided to seek a $4 million endowment to give the program a secure future. Both the New Haven schools and Yale see that they are pursuing their self-interest through participating in the Institute.

- Senior and prestigious Yale faculty are involved from a range of disciplines. Yale does not have a school or department of education and, in the view of one observer, this is a blessing. He states, "Without an intermediary buffer, softening, exaggerating, or explaining away the contrast of intellectual milieu between secondary education and higher education, the two groups of teachers (New Haven school teachers and Yale faculty) are free to explore for themselves the extent to which they share values and assumptions about their subject and its role in the development of children's minds and characters."

- Teacher participants in the Institute are designated as Institute Fellows. They are remunerated, each fellow receiving an honorarium on successful completion of the program. Fellows are full members of the Yale community; they are listed in the university director of faculty and staff; this has symbolic meaning in recognizing them as colleagues and practical value in making Yale resources readily accessible to them.

- The administration structure reflects the primary of teachers. Leadership is provided by a small group of teachers, designated as Institute Coordinators; the project has teacher coordinators in each participating school. Also, the program has had the same director since its inception in 1978, and he has guided the program with great skill, bridging the gap between the university and the community.

Conclusion

I have identified one topic within the general area of scientific and engineering talent that requires greater understanding, that is, the flow of the most talented students into graduate programs in the sciences, mathematics, and engineering. Existing data do not indicate that there is a problem in this area, but neither do they provide assurance that there is no problem. Because the most talented students are so critical to scientific and engineering advances, and because there are reasons to be concerned about the future supply of such talent, we would do well to understand more about the current supply and about the factors that influence the decisions of these students to pursue graduate education and research careers.

Second, I have identified a range of programs that can be considered to be at least, in part, a kind of scholar/practitioner network. All of these programs are considered to be successful. From this diverse set of successful networks, I have derived a list of principles for creating scholar/practitioner networks for the purposes of stimulating discussion.

- By definition, scholar/practitioner networks must include scholars and practitioners--and they must include the best scholars and the best practitioners to demonstrate that the activity is legitimate and to encourage broader participation from both communities. The teacher/practitioners must be included in meaningful ways and be given leadership and decision-making responsibilities.

- The network must involve the direct participation of senior officials with policy-making and decision-making responsibilities from the institutions in which the activities of interest take place--i.e., government agencies, schools, universities, museums, etc. In education, the translation of new knowledge and new programs into practice requires more than the commitment of individual scholars and practitioners; it requires institutional commitment throughout the multilayered education bureaucracy. Thus, participation by individuals who can commit their organizations is required.

- The subject addressed by the network--as, for example, the most capable youth in mathematics, science, and technology--must be viewed as high priority and intellectually challenging by all participants. Everyone must view the problem as worth solving; everyone must perceive that they will derive a benefit from participation in the network process and from reaching a solution to the problem. Self-interest unevenly distributed among the participants will result in the exploitation of one or more groups and failure; self-interest evenly distributed among the participants is essential for success.

- Establish near-term and long-term objectives. Accomplishments in the near-term are essential to maintain the interest and commitment of all parties. The network should be established for the long-term.

- Cooperation and collaboration cost money, take time, and require perseverance. There must be an organizational structure and staff with the clear, ongoing responsibility for establishing and maintaining the network--it will not continue with "a momentum of its own." There must be ongoing financial support for the business of the network and for the organization and people who operate it. The challenge is how to do this without creating the reality or the perception of just adding layers of bureaucracy to the system.

- Flexibility--both organizational and financial--is required to respond to variations in conditions, in the nature of the problems, and in opportunities. The necessity to satisfy the many different participants in the network requires the ability to respond to a variety of demands and to take advantage of special opportunities when they arise.

- Any network is foremost a process, and success depends on the quality of interpersonal interactions and relationships. Skillful, imaginative, and delicate leadership is required to select the core participants in the network and to facilitate this intensely personal process. Delicacy is important because it is the core participants in the network and the problems they are addressing that must be the center of attention; the facilitating organization and individuals must find a way to exercise leadership but to remain in the background.

- The sponsoring organization(s) of the network, which also may be the home for the operating unit, must be held in the highest regard by all of the participating groups. This issue of quality runs throughout the principles. Establishing and operating a network is difficult; there are lots of reasons for it not working. The only hope for success is that the individuals and institutions involved in the core of the operation be the "opinion leaders" in their peer groups.

There is one feature of any network that is notably by its absence from the above list-the level at which it is organized, i.e., local, state, regional, or national. I find myself considering several different factors related to this question and unable to put forth a single principle. Therefore, I simply raise some of these factors as a basis for further discussion.

The success of the local models--the Urban Mathematics Collaboratives and the Yale-New Haven Teachers Institute--is compelling. Our educational system is grounded in state and local autonomy; local conditions vary; local problems vary; and the institutions and individuals who can best bring the practitioner and scholarly communities together also vary. Theodore R. Sizer, in evaluating the Yale-New Haven Teachers Institute, stated: "The arguments for the current scale are powerful. All too few school 'reform' efforts to get the scale right; almost universally they are too ambitious . . . by remaining small, focused and uncomplicated, the Institute will serve its purpose admirably."

On the other hand, much activity in education is based on national models--for example, textbooks, teacher education, and much of testing. Furthermore, many of the educational reforms called for are national in scope--for example, curriculum reform, teacher rewards and working conditions, and increased attention to the most capable youth. The objectives of education are becoming less influenced by local conditions and more by national and even international needs. While comparisons and competitions among local schools will continue, we see an increase in comparisons of the U. S. with other countries, and we see the results of these international comparisons used as a basis for school and curricular reform. Finally, I think of the current situation in agriculture. With a long-standing focus on research and extension at the state and local levels, substantial improvements in agricultural productivity have been achieved. Now the system is criticized by some for giving insufficient attention to research areas, most notably biotechnology, that could have a profound national and long-term impact on agriculture.

In considering the local-national axis for scholar/practitioner networks, the answer is probably that both are required--local and national. And, to use a well-worn metaphor in this area, the goal is to weave the local networks into a national fabric that will cover local and national concerns in a balanced manner. The metaphor is well-worn, but the fabric is not. Although often proposed as an approach to the nation's educational needs, I do not think we have achieved it. The Mathematical Sciences Education Board is a recent attempt at such a combined, national-local approach. How do you think a "network of networks" could be established to address topics related to the most capable youth in mathematics, science, and technology?

Notes

1. The views expressed here are mine; they do not represent the views of the Research Roundtable Council nor of its sponsoring organizations, the National Academcy of Sciences, National Academy of Engineering, and Institute of Medicine.

2. Solmon, Lewis C. and La Porte, Midge A. (1986). The crisis of student quality in higher education. *Journal of Higher Education,* Vol. 57, No. 4, 370-392.

3. Goldberg, Frank and Koenigsknect, Roy A. (1985). The highest achievers: Post-baccalaureate Enrollment of Four Classes Between 1956 and 1981. Consortium on Financing Higher Education, Northwestern University.

4. Hartnett, Rodney T. (1985, March). *Trends in student quality in doctoral and professional education.* Rutgers, NJ: Rutgers University.

Attachment I

Choice of Undergraduate Major
Data in Support of Figure I

	1967		1975		1983	
	Enrollment Share	**Quality Share**	**Enrollment Share**	**Quality Share**	**Enrollment Share**	**Quality Share**
Biosciences	3.7	6.2	6.3	12.9	3.8	7.6
Engineering	9.5	10.0	7.9	13.3	11.7	19.2
Physical Sciences	7.2	21.3	3.8	11.5	2.6	7.1
	20.4	37.5	18.0	37.7	18.1	33.9

Source: Solmon, op. cit.

Attachment II

The change between 1981 and 1985 in the percentages of freshmen intending to major in various science and engineering disciplines who had A+/A/A- high-school grade averages.

The following increased by more than 10 percentage points:

Anthropology	+22
Botany	+20
Industrial Engineering	+16
Microbiology	+13
Chemistry	+12
Biology	+10

The proportion of top students in the following fields decreased by more than 10 percentage points:

Statistics	-24
Geography	-18
Astronomy	-16
Zoology	-16
Sociology	-15
Atmospheric Science	-12

The percent of students who graduated in various science and engineering majors who were top students (those in the 1981 freshman cohort who earned B+ or better averages in 1985).

The following majors had more than 40 percent of their students fall in this high-achiever category.

Astronomy	100%
Statistics	100
Anthropology	94
Biochemistry/Biophysics	64
Physics	62
Botany	47
Mathematics	45
Aeronautical/Astronomical Engineering	44
Chemistry	44
Biology	42
Chemical Engineering	41

Attachment II (continued)

The following majors had less than 40 percent fall in this high-achiever category:

Industrial Engineering	32%
Electrical Engineering	30
Zoology	28
History/Political Science	28
Psychology	27
Economics	23
Mechanical Engineering	23
Earth Science	21
Sociology	17
Microbiology/Bacteriol	7
Geography	7

As points of contrast, the comparable figure are:

Premedicine/dental/veterinarian	29%
Business	18

Persistence rates by field and field-switching patterns with A averages at the time of receipt of the bachelor's degree. Persistence rates for A students by field were:

Mathematics	87%
Physical Sciences	85
Engineering	74
Life/Environmental Science	68

Students with A averages defecting from science and engineering fields primarily took the following directions:

From Mathematics to Physical Science	13%
From Physical Science to Engineering	12
From Engineering to Physical Science	10
and to Biological/Environmental Science	9
From Life/Environmental Science to Social Science (22%) and Business	5

Source: Holmstrom, Engin Inel. "Quality of Students in Sciences and Engineering: Change or Stability?" Draft report submitted to the National Academy of Sciences, August 31, 1987.

Attachment III

GOVERNMENT-UNIVERSITY-INDUSTRY RESEARCH ROUNDTABLE

ROUNDTABLE COUNCIL MEMBERS

James D. Ebert
CHAIRMAN, Roundtable
Director, Chesapeake Bay Institute
The Johns Hopkins University

Orville G. Bentley
Assistant Secretary for Science
and Education
U. S. Department of Agriculture

Joel S. Birnbaum
Vice President and General
Manager - Information Technology
Group
Hewlett-Packard Company

Erich Bloch
Director
National Science Foundation

Richard F. Celeste
Governor
State of Ohio

Marvin L. Cohen
Professor of Physics
Physics Department
University of California, Berkeley

William Danforth
Chancellor
Washington University

James F. Decker
Acting Director
Office of Energy Research
U. S. Department of Energy

William R. Graham
President's Science Advisor and
Director, Office of Science and
Technology Policy (OSTP)
Executive Office of the President

Kenneth H. Keller
President
University of Minnesota

Ronald L. Kerber
Deputy Under Secretary of
Defense for Research and
Advanced Technology
U.S. Department of Defense

John D. Macomber
Chairman
J. D. Macomber and Company

Frank Press (ex officio)
President
National Academy of Sciences

Nathan Rosenberg
Professor
Department of Economics
Stanford University

John E. Sawyer
President Emeritus
Andrew W. Mellon Foundation

Rudi Schmid
Professor of Medicine and
Dean, School of Medicine
University of California

Howard A. Schneiderman
Senior Vice President for R&D
The Monsanto Company

Attachment III (continued)

Ben G. Streetman
Professor of Engineering
University of Texas at Austin

Samuel O. Thier (ex officio)
President
Institute of Medicine

Alvin W. Trivelpiece
Executive Officer
American Association for the
Advancement of Science

Thomas N. Urban
President and Chairman
Pioneer Hi-Bred International, Inc.

Robert M. White (ex officio)
President
National Academy of Engineering

Linda S. Wilson
Vice President for Research
University of Michigan

James B. Wyngaarden
Director
National Institutes of Health

Discussant Reaction: Creating Scholar/Practitioner Networks for the Most Capable Youth in Mathematics, Science and Technology

Raymond Hannapel

Don Phillips gave us some interesting examples of networks. His focus on the Mathematics Science Education Board (MSEB) is very interesting because it is an attempt by the Academy to draw in several partners. The Academy is making a long term commitment to providing national leadership in the reform of mathematics education in the United States. It is a very ambitious undertaking, but terribly necessary. Their efforts are certainly of interest to this conference, and indeed to the whole professional community interested in increasing the talent pool in mathematics.

Several of the collaborative efforts and networks that Dr. Phillips chose were aimed at the issue of mathematics or science or trying to improve the quality of the experience for all students. That's just the place to start if you are going to think about talent development. I worked with the National Science Board Commission on mathematics, science, and technology education that developed *Educating Americans for the 21st Century,* which was a long term plan for trying to address the issue of improving science and mathematics education at the precollege level, the elementary and secondary school level. It became very obvious when looking at all the evidence that the Commission looked at that the most important aspect was to increase the quality and the quantity of science and mathematics experiences for younger children. That's the place to start, and that was a good point to draw into this.

What I would like to focus on is the question that Dr. Phillips used to end his paper: How do you think a network of networks could be established to address topics related to the most capable youth in science, mathematics, and technology? I'd like us to think about that issue, but I'd like to rephrase it a bit: What kinds of networks could be established that would cultivate talent in youth in mathematics, science, and technology? What kind of networks would generate niches where interested young people would be provided both with exposure and experience to what I would like to call the 'culture of science'?

When we try and juggle with these questions I would submit that if we're really concerned with the culture of science, and here I mean mathematics as well, we need to think about providing experiences for youth in a locale where things are going on. But because of the nature of the culture of science, not just local, or just national, it's giving students access to an international kind of subculture.

What do I mean by that? Let me back off just a minute and raise a couple of questions about the nature of that experience and what it might be before I go into some suggestions I have for a network of networks, and address Dr. Phillips' question. I found a provocative paper by Ken Bolding very instructive here, and I'd like to run through some of its main points. This was the American Association for the Advancement of Science (AAAS) Presidential address in 1980 (*Science*, January 1981). Its called "Science: Our Common Heritage." Bolding does an historical and logical analysis of the nature of science, how it developed, and how it has become a keystone of western culture. He attempted to do an analysis of the value of the belief structure of that subculture.

Bolding noted that the most important value in the enterprise of the subculture of science is the high value placed on curiosity. The value of the good question as opposed to having all the right answers. The value of the good question combines with the high value placed on the interplay between imagination and reality. There's an element of fantasy and imagination coupled with logical reasoning that essentially invents descriptions, theories, whatever. But fantasy and imagination are always anchored in the test of reality in the real world, and that's another important attribute.

Bolding makes another point about veracity, and how important veracity is to this whole enterprise: recognizing your data for what it is. The quickest way to get drummed out of a court is to falsify results. It's very critical being able to depend on another person's data, recording it faithfully and accurately. He makes an interesting point about something that developed in this subculture that was not very pervasive in the 1500's, the 1600's: the legitimacy of error. Trial and error is the keystone of reality testing, so error is very important. You learn a lot from making errors. Finally, he talks about the development of the last attribute and that is the replacement of coercion with persuasion. That was a source of trouble very early on between science and the Establishment. Something important to think about as we think about networks is what will foster talented youth in science and math, because doing science, doing mathematics is really a generative process--it's creating human knowledge, inventing new anxious.

Very often, academic experience, and this is true not only in elementary and secondary schools, but in colleges and universities, provides a preponderance of knowledge acquisition for students. It's important to keep our focus on the issue of *making* mathematics and *making* science as a key experience for young people, when we're concerned in developing talent. I believe that we ought to do this for all our students, but I think it's especially important to be clear about this with people who are going to do science and mathematics in the society.

With that as a little bit of background and with some of the criteria that Don Phillips ended with in his paper, I'd like to tell you about a new initiative at NSF which is really a resurrection of an old and successful program, the Young Scholars Program, that was just initiated this year.

It took several years to persuade the Office of Management and Budget that the Young Scholars Program was important and to allow the NSF to get back into this activity. Some of you may remember something called Students Science Training (SST) Program that was around for 20 years at NSF. The idea of the program is to establish a number of new projects, and also to establish programs that persisted in the absence of support of NSF to make them better. I have an example of such a program. I don't know how many of you know Arnold Ross, who's a premiere mathematician, highly regarded at Ohio State. Arnold had been working with high school students for several years with support from the this SST program. Arnold's and several other programs have persisted when support was cut off in 1981 from NSF, mainly because the whole class in engineering education program was curtailed. There is an opportunity now for these programs to augment what they're doing, to provide scholarship activities to students who can't afford the tuition, and some of them are very expensive as you know--

anywhere from $1,200 to $1,800 depending on the length and nature of the experience.

The program also provides support for several new activities, and allows the opportunity not only for scholars and researchers working with young students, but also for scholars working with teachers and students. So the funded group can be teachers and students. There are all kinds of flexibility in participating in the program. But the key features of these programs are really the *nature* of the activity. Let me read something from the program notes, some advice we give to proposers:

> Proposers should keep in mind that students learn science best by practicing science, that is, by exercising the natural curiosity and engaging in scientific research and discovery. Projects may consist of any combination of activities involving instruction, problem solving, and exposure to the research environment and research methods that are appropriate for the target age group and the discipline focus. Activities should be strong, be participatory, be intellectually challenging and promote positive interaction among the students and the staff. Proposers are encouraged to design innovative methods and approachers and should strive for a balance between lecture, laboratory, field, and research experiences. Young Scholar Projects are not intended to provide course work primarily designed to prepare students for Advanced Placement, or to duplicate regular college courses.

The intention here is to provide a range of disciplinary opportunities in locations at some of the top university research laboratories, field stations, and industrial and government laboratories for our best students. A second intention is to establish a network of collaboration among the project directors. That will be done through regular meetings of the actual project directors. There's additional information in the program note. I won't go into detail, but the important components should include follow-up activities with these young people, as well as with career exposure.

Another activity that is up and running at NSF is a program in the area of teacher enhancement called Science and Mathematics Networks. This program is specifically targeted at providing the kinds of support to projects with the attributes Phillips was mentioning: where there is a sharing of responsibility and of the benefits of collaboration. One example of a project is referred to as the Triangle Coalition. It's a coalition of business, industry, science and engineering research, schools and academic scientists and mathematicians. Some of the initial projects have been the promotion and facilitation of quality science experience in elementary schools. There is a network of these people supported by the Networks Program at NSF.

There was also a program announcement for business partnerships and soon there will be an announcement of awards from that solicitation. Those are a variety of collaborations between community groups, business, industry, school board, community leaders, schools and universities, or other agents such as science museums or field stations.

I should tell you a little bit about the level of funding, especially the Young Scholars Program. The program is being funded at a little over $3.5 million this year. In the next fiscal year, that's the budget that's being considered by the Congress, that's due to double to $7 million. It's a very important priority of the National Science Foundation. It also enjoys the support of Eric Bloch who is the director in the National Science Board. It was solely due to two years of lobbying the Office of Management and Budget by Eric Bloch that program was started. So, those are some examples from NSF, and I would just end by saying let's consider some others. I think Dr. Phillips' question is a good question.

Discussant Reaction: Creating Scholar/Practitioner Networks for the Most Capable Youth in Mathematics, Science and Technology

Gregory A. Kimble

Because of what highly talented people potentially can do to improve the human condition, the nourishment and preservation of their talent is a matter of great importance. Although people with other specialties may make equal contributions, the support of those with skills in science and mathematics is particularly urgent in this age of high technology. One measure of success in the achievement of this goal is the number of people who receive the Ph.D. degree in some branch of science or mathematics.

Over the last 20 years, in American universities there has been a general increase in the number of individuals who receive their Ph.D.'s in science. For a moment one might conclude that we are doing very well. Details of the data reveal, however, that there are reasons to draw conclusions with more caution than that. In the physical sciences, the number of Ph.D.'s has bucked the trend and is down by 20 percent. Meanwhile, the number of Ph.D.'s in the applied field, Engineering, has gone up by something like the same amount. In psychology, there is a very much exaggerated version of this same pattern. Since 1967, the number of Ph.D.'s in research/academic psychology has declined by 20 percent, while the number awarded to health service providers has trebled.

The reason for the pattern just described is economic. People are preparing themselves for occupations that are practical, well paid and available. Partly as a result of these incentive factors, science is falling behind in the number of undergraduate majors that it attracts. In particular, the best and brightest students are staying away in droves. The other causal factor that is keeping students out of science and mathematics majors is inadequate preparation. Too many of them find out in the first college course they take in science that they lack the skills that are taken as assumed prerequisites. In recent years, American education in science and mathematics at the secondary level has been lagging. It has now deteriorated to the point where the United States has the status of a disadvantaged nation in this regard.

Structures called "scholar/practitioner networks"--it would be more accurate to call them "scholar/administrator/practitioner networks"--have been created as a means of dealing with the shortcomings of science education in America. These networks, made up of people who are committed to the program, able to work together and blessed with appropriate expertise, undertake a wide range of activities and support a wide variety of projects aimed at improving the situation of science in our country. They encourage research, support symposia and workshops, offer fellowships and internships, establish policy and priorities, and facilitate communication through meetings and publications.

As short-term goals, these accomplishments are to be applauded. It is unclear, however, whether they are having any impact on the problem at its source, the reluctance of society to provide adequate support for scientific education and research.

Figure 1

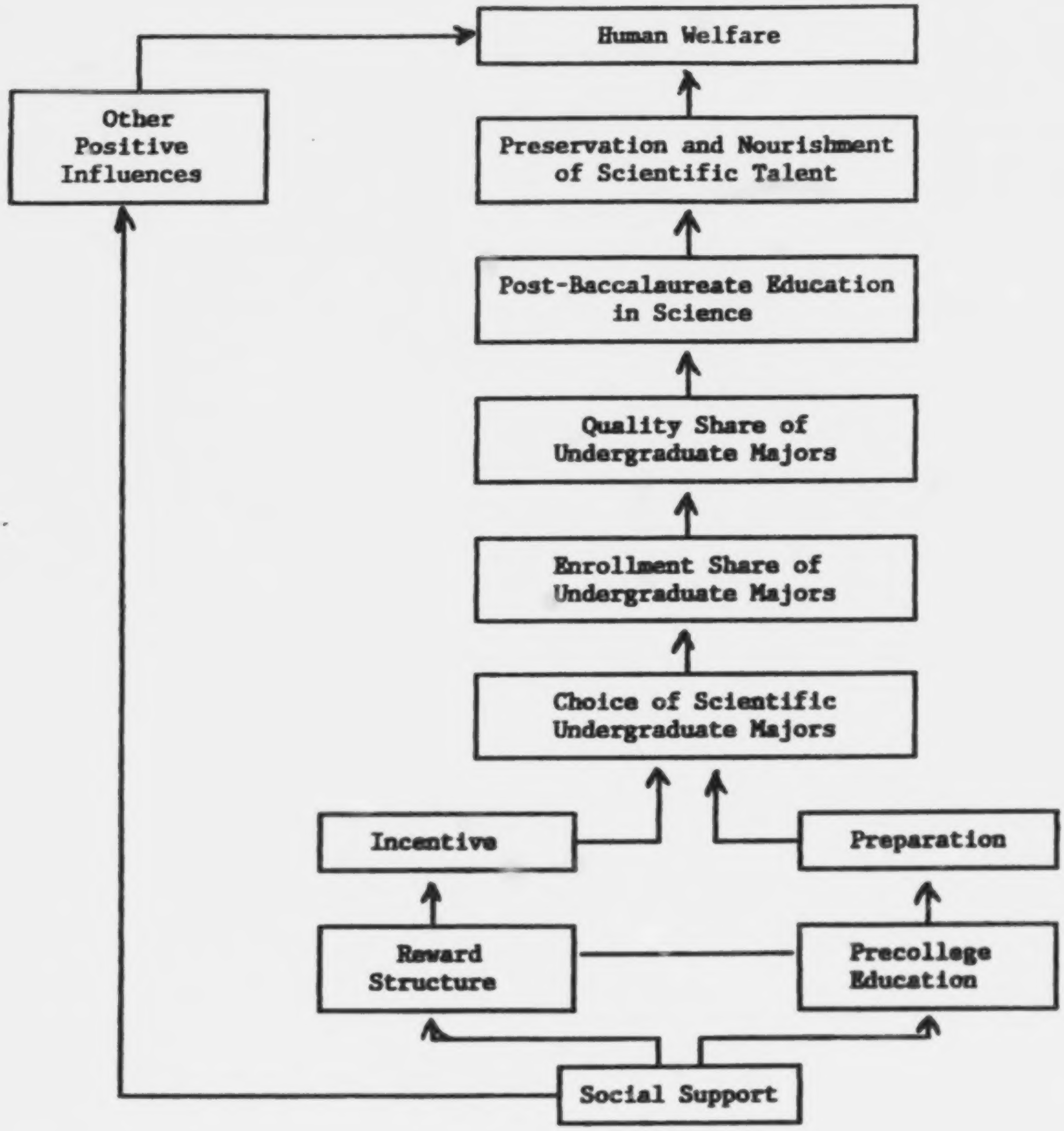
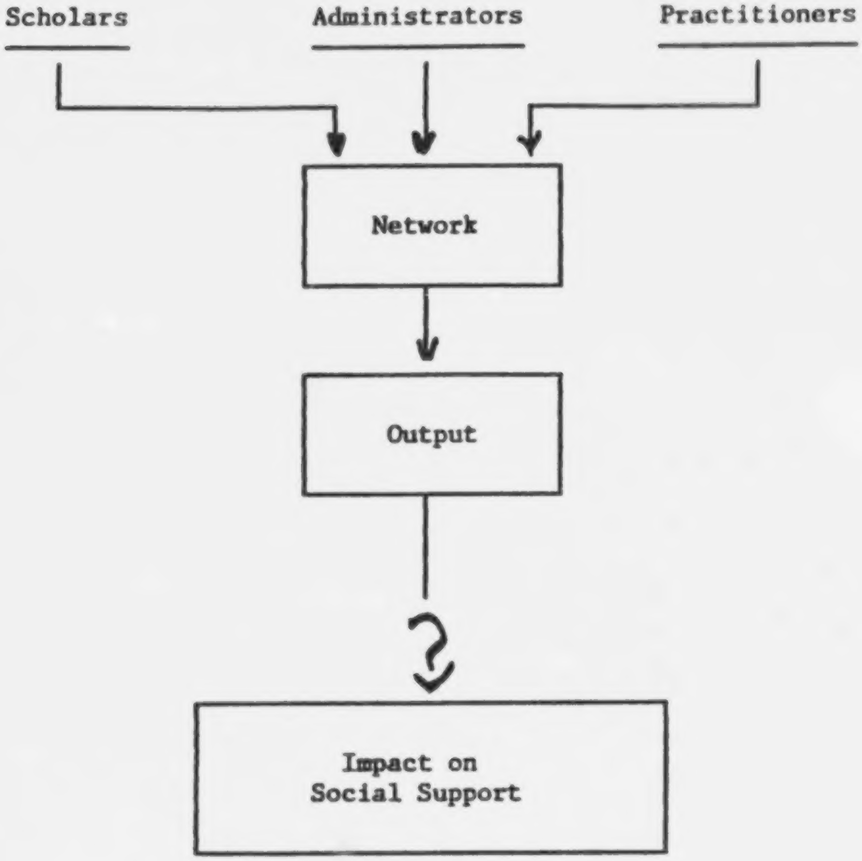

Human Welfare
Other Positive Influences
Preservation and Nourishment of Scientific Talent
Post-Baccalaureate Education in Science
Quality Share of Undergraduate Majors
Enrollment Share of Undergraduate Majors
Choice of Scientific Undergraduate Majors
Incentive
Preparation
Reward Structure
Precollege Education
Social Support

Figure 2


Scholars
Administrators
Practitioners
Network
Output
?
Impact on
Social Support

BRILLIANT WOMEN FOR SCIENCE, MATHEMATICS AND ENGINEERING: GETTING MORE THAN WE DESERVED?

Shirley Malcolm

"It's a girl!" The news of the arrival of a daughter all too often signals the beginning of a pattern of socialization that may extend even to the choices of career in adulthood, independent of her interests or aptitude. Her pink booties give way to ballet slippers. The gentler pattern of play and interaction by her parents while she is an infant is often followed in her childhood by expectations and assumptions about her toys *and* her abilities in mathematics. Breaking this cycle of socialization may be necessary if we are to attract and retain highly talented young women to science and engineering careers.

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In 1986, women were about 44% of all workers in the United States workforce, a comparable percent of all professional and technical workers, but only 15% of employed scientists and engineers. While this proportion is low, it has increased, tremendously, since 1976 when women were only 9% of scientists and engineers. Women's participation is higher in science (around 25%) than in engineering (around 4%). Scientists and engineers are made, not born. Finding the raw talent, cutting and polishing it to its full brilliance, is responsibility shared across our schools, our colleges and universities, and the science and engineering communities.

Early identification of talent for science, mathematics and engineering means identifying (or making certain assumptions about) the characteristics most likely associated with people who are scientists, mathematicians and engineers. This is usually done by referring to characteristics of the present population of professionals in these fields. These elements may include personal attributes such as interest, curiosity, persistence and hard work, coupled with above average intelligence. No matter how strong these aspects are, however, we generally accept the notion that a suitable environment to learn, encouragement and the guidance of teachers and mentors are essential to having the potential for science expressed as performance and achievement in these fields. We must look both at the personal attributes they bring and the way these interact with the environment they encounter to determine if talented young women are receiving the experiences that would encourage or support their choice of a science career.

Since our reference points for identifying talent have been the males who have dominated these careers, we may not have included those attributes of potential women scientists who, unable or unwilling to buy into the image, may have been left behind. We may agree that intellectual capability is central, but may disagree on the narrowness of current measures used to assess this. Clearly, our society is geared to believe that, at least in mathematics learning, ability is of prime importance; you can identify it early and it is immutable - you either have it or you don't. In a recent survey of American and Japanese mothers, both groups were asked about the reasons for school success in mathematics. The American mothers attributed this to ability; the Japanese mothers attributed such success to effort! If we ignore for a moment the issue of test bias, what do the tests tell us about the capability of girls and boys to do science?

If we used measures of achievement by nine year-old on the National Assessment of Educational Progress in science, mathematics and reading as proxy measures of educational capability, all else being equal, we would expect to find females as numerous as males in science, engineering and mathematics based careers. At this point, girls perform as well as or better than boys on the NAEP mathematics test in all tested areas including knowledge, skills, understanding and applications. Science scores are slightly higher for nine year old males on all components, with the largest difference (2.6 percentage points) on the attitude component. (Reported in NSF, 1988.) Nine years old females outperform nine year old males on the NAEP reading test (NAEP, 1985).

At thirteen years of ages, score differences between males and females become larger and begin to favor males, especially in science. Mathematics scores are still very similar between the two groups: girls score slightly higher on the skills component of the test, and boys score slightly higher on applications. On the NAEP science test, males outscore females, with performance differences of more than four percentage points on science, technology, and society; content; and attitude. Females maintain their performance advantage over males on the NAEP reading test.

By seventeen years of age the score differences in mathematics and science on NAEP have increased in favor of males. The female advantage in reading is maintained for 17 year-olds.

How do girls who start off even or superior to boys in their performance in mathematics fall progressively behind over time? Why are score differences present from the first point of testing in science; and why do they become more pronounced over time? A number of possible explanations exist, including:

- Males and females take different science and mathematics courses in school;
- Males and females have different experiences in the classes which they share; and
- Males and females have different out-of-school experiences which affect their test performance.

Different Courses

Based on data from High School and Beyond (HSB) we find that females are as likely as males to enroll in an academic level high school program. We find that young women take fewer mathematics and science courses in high school but have higher grade point averages than young men. If we look at specific courses, we find that females are about as likely as males to attempt algebra I, geometry, algebra II, biology and chemistry. On the other hand, 25.8% of males and 20% of females attempted trigonometry; 9.9% of males and 7.8% of females attempted analysis and 8.2% of males and 5.7% of females attempted calculus in high school; 5.2% of males students attempted chemistry II, compared with 3.6% of females. The male advantage in physics was substantial. Over 22.1% of young men and only

11.6% of young women reported attempting physics. Advanced physics was reported taken by 2.6% of men and 0.9% of women in the study (Reported in NSF, 1988).

Clearly, the young women in the nationally drawn HSB population were not getting the same course experiences as the young men. So, the fact that differences in performance occur among 17 year-old should come as no surprise.

Any differences that are seen for 13 year old males and females, even small ones, are not as easily explained, however, since presumably, at this point all students take the same courses.

What other factors might be at work to account for differences seen between female and male students' performance in science and mathematics?

"A Different World"

In a paper presented at a National Research Council conference, "Women: Their Underrepresentation and Career Differentials in Science and Engineering" Matyas and Kahle summarized the research on pre college factors affecting the achievement of females in science and mathematics education; they found the following:

- Girls and boys enter elementary school with equal interest in science but with unequal experiences.
- Girls and boys have different out-of-school activities, with boys having more opportunity for hands-on experiences that are important for in-school science and mathematics learning.
- Girls and boys have an image of scientists as being white, male and "nerdish/bookish".
- Girls have less opportunity than boys to handle equipment, perform experiments and undertake other science activities in the classroom.
- Boys are expected to perform better in mathematics than girls and receive more teacher interaction on their mathematics performance.
- Teachers, especially in mathematics and science, call on a small target group of students (mostly boys) in the classroom with whom they interact for longer periods of time.
- Boys tend to be asked higher cognitive level questions than girls.

The picture that emerges is one in which female students, even while taking the same classes as male students, are drastically shortchanged in their science and mathematics experiences and opportunity for interaction with the teacher; they are outsiders, bringing neither the base of out-of-school experiences nor enabled with appropriate in-school ones. They are not expected to do well in science and mathematics, and often they fulfill these expectations.

A particularly troubling finding which was presented by Matyas and Kahle was the experimental study of Spear, where science teachers were asked to evaluate the sample work of students.

> When teachers believed that the work had been done by a boy, it was judged more scientifically accurate, possessing better organization and richer ideas, and more concise than when they believed a girl had done the same work. Girls' work was judged to be neater than boys' work.

Other instances of differential behavior cited included the work of Gordon and Addison who documented that teachers are more likely to nominate boys of average abilities for special programs before girls who are gifted.

In attempting to piece together a picture of how these various factors may interact in women's decisions to participate or not to participate in science, Chipman, a discussant at the NRC conference, posed the following model (Figure 1). She suggests that two major factors contribute to the participation---"expectancy of success and value assigned to outcome." Each of these factors she suggests is affected by many other inputs (Figures 2 and 3). She states, "for individuals, it is clear that cognitive ability is an important predictor of persistence in mathematical, scientific and technical fields, but it is rather unlikely that sex differences in ability contribute significantly to the observed sex differences in participation.

Chipman goes on to suggest that different interest patterns and *confidence in ability* may provide some explanation for observed sex differences in participation.

What are the relative roles of interest, ability, "preparedness," confidence in ability and competence in determining females' participation in science careers? Are you born interested in science and mathematics and made uninterested? And, can interest, unmade or unborn, be stimulated?

If we believe, as evidence suggests, that young children are born curious, possessing all the qualities of inquisitiveness, exploration, wonder, openness and excitement which we attribute to "good" scientists, then we must look to those later experiences and interactions with the adult work to determine how that interest is reduced.

Chipman questions whether interest in science, mathematics and technology is spread across the population in the same way and whether we should expect to find it manifest among men and women to the same extent. Chipman's question is put in a different light when we realize that one can find islands of equity spread across the landscape of the United States educational system--classrooms and schools where young women are as likely to be enrolled in advanced math and science as young men. And, the teachers of those classes expect as much from the female students as they do from the male, call on members of both groups equally, wait for their answers, equally encourage their participation (Casserly, 1983 & Kahle, 1983).

Changing Habits of Mind

In 1973 sociologist Lucy Sells looked at the entering freshman class at the University of California at Berkeley and noted the different ways that men and women were distributed among the major - the men dominated in majors of engineering, mathematics and natural science, the women in the social sciences, humanities and education. She confirmed this same distribution among majors at the University of Maryland. Sells found the connection between majors and gender and the mathematics courses taken in high school. Even if the women decided that they were interested in civil engineering or chemistry, they were too often prohibited from choosing this major because they had not taken the requisite levels of mathematics in high school. In making a choice that was possible, given their mathematics preparation, these women were limited to those majors that did not require four full years of academic track mathematics. Mathematics came to be described as the "critical filter" for careers in science, mathematics and engineering, and a program of research and intervention was begun which has occupied scholars and activists alike for almost a decade and a half. These have included interventions, mostly from the middle grades through college, as with the women in engineering programs.

Intervention programs were developed that focused on:

- Trying to get able young women to keep their options open by continuing to take mathematics courses offered at the high school level, and

- Conveying the *value* and *utility* of mathematics to women's lives and to later career decisions.

Such programs took the form of career education workshops such as "Expanding Your Horizons," developed by the Bay Area Mathematics/Science Network, that focused on informing students and parents about the importance of taking mathematics in high school. Programs for teachers and other school personnel, such as EQUALS of the Lawrence Hall of Science, University of California, Berkeley, quickly spread across the United States. Attention to mathematics as a "critical filter" was paid in books, magazines and newspaper articles, films and film strips. Sex equity programs that resulted from federal enforcement of Title IX, included mathematics and science prominently among their concerns.

The Women in Science Program of the National Science Foundation (NSF) was a primary source of support from women's intervention programs, funding 136 projects between 1976 and 1981. The Women's Educational Equity Act (WEEA) program, established in 1974 at the Department of Health, Education and Welfare was another major source of funding for science-related programs under its general mandate to support the movement of women into careers non-traditional to them.

While it is difficult to document the direct effect of a single exposure career day on the life of a young woman, one sees amazing correlation between the onset of the "movement" in the early 1970's of which the career days were a part, and the upward climb of degree output by women over the succeeding decade. In 1972, 501 women received bachelor's degrees in engineering. By 1980, 6,014 women received such degrees, and by 1982, this number had reached 8,231. (Vetter and Babco, 1987) In 1986, women received 11,049 engineering bachelor's degrees, or 14.5% of the total awarded.

In summary, the steps leading to altered high school course-taking for young women in the late 1970's and 1980's seem to have been:

- The identification of mathematics as a "critical filter" to science and engineering, and indeed to many other professional careers, as well;
- The dissemination of this information and initiation of intervention programs to affect young women's choices by stressing the utility of elective mathematics course taking; and
- Programs aimed at teachers and parents to inform them of their role in high school mathematics course taking by young women.

While career information about all kinds of fields, especially non-traditional ones, was delivered, the focus of the message was clearly to "keep your options open" for many different futures that might await. Clearly, an increased number of young women, their teachers and parents got the message. Young women became distributed in engineering fields, for example, where only a few years before, they had been only a token presence.

Interest

If we believe that little girls start out with as strong an interest in science and as much ability as little boys, where might we look for an explanation of the differences that emerge:

- Who teaches science? One could argue that students receive a clear message about females' place in science from the role models in the classroom. According to Weiss, in grades K-3, teachers spend an average of 19 minutes per day on science instruction; this increases to 38 minutes for grades 4-6. While this mostly female teaching workforce enjoys teaching science. Few feel that they are "master" teachers in the subject with over one-fifth feeling they are not well qualified to teach physical science or earth/space science. By high school, the science teaching workforce has become overwhelmingly male (68%), and a full 61% agree or strongly agree that they consider themselves a "master" teacher in science. The perceived (and actual) competence in teaching science increases as the female proportion decreases.
- How is it taught? Science is typically taught with more time spent in lecture and discussion than in hands-on lab experiences. Teachers overwhelmingly agree that hands-on classes are more effective. Research supports the particular effectiveness of this technique when used with minority and female students. But, there is a large discrepancy between the most desirable and the actual conditions for learning. There is heavy reliance on textbooks which have tended not to show an active role for girls and women in science. As grade level

increases, the amount of time spent on lecture and "whole class activities" increases while the proportion of time spent on small group activities decreases. Small group activities and team project activities have been shown to be particularly effective for female students. (Malcolm, et al., 1984).

- What is taught? There are those who would say that the content of science and mathematics courses are free of bias. It is not difficult to point to problems and examples that draw on the experience of boys rather than girls. Questions of bias in the presentation of content are relatively new areas of exploration. But only a few examples are required to point out how this might work. In all my black inner city high schools in Birmingham, we "learned" about vectors using text-based examples of sailboats--something that few, if any of us had seen, no less experienced. Discussions of social organization often draw on language such as "dominant" male, harem and the like. We talk about a man-made world; and, only white men did important things in science since they dominate in the texts. Women are left on their own to draw conclusions as to why they are "missing persons." Students are not told of important figures who worked in spite of the odds, in spite of barriers erected to keep women out.

College Bound

If you look at the characteristics of college bound students based on the Admissions Testing Program of the College Board, we find major differences in self-report of the high school studies and intended areas of study for male and female students in 1985:

% of Students Taking	**Male**	**Female**
- 4 or more years of math	73.0	60.9
- 2 or more years of biological science	33.3	36.6
- 3 or more years of physical science	33.3	20.0
% of Students		
- Having 3.50 g.p.a. or above	34.4	27.0
- In top tenth of his high school class	20.5	21.9
% of Expressing as First Choice Intended Areas of Study		
- Agriculture	1.4	0.6
- Biological Sciences	3.0	3.1
- Forestry/Conservation	0.6	0.1
- Health and Medical	9.1	19.0
- Computer Science/Systems Analysis	9.4	5.0
- Engineering	21.1	3.4
- Mathematics	1.2	1.1
- Physical Sciences	2.5	1.0

The problem of attracting women to science, mathematics and engineering is not solved. Able young women who are headed to college are still making different choices of majors than able young men. Subtle social factors often play a role in their decisions.

The Times Are A'changin'?

Looking at the 20 year trends in *The American Freshman* we find that women's aspirations for the doctorate and professional degrees have increased tremendously, with fully 18% of women compared to 19.6% of men indicating that they planned such a degree. Over the same period, women's interest in education decreased, from 17.5% in 1966 to 10.4% in 1985; their interest in business skyrocketed from 10.9% in 1966 to 23.8% in 1985; and their expected participation in engineering increased from 0.3% in 1966 to 3.0% in 1985.

In 1967 over 44% of women agreed strongly or agreed somewhat with the statement "The activities of married women are best confined to the home and family." By 1985 the number agreeing had dropped to 16.0%, and by 1987 it had risen slightly to 20.3%. By contrast, 66.5% of men in 1967 agreed with this statement and 29.5% in 1985. By 1987 this number had risen to 32.3% of freshman males. Is commitment to a career in science compatible with this view of the role of women? Clearly, young women's perception of the conflict of career and family must be addressed; and even more so, the perception of young male students. Ultimately, the reality of these conflicts must be dealt with by the society at large. These attitudes fly in the face of the reality of the world today, since we know that most of these women will work outside of the home. And the faculty makeup of most colleges and universities, especially in science and engineering, and the status of these women in science does little to send an alternative message.

Special Populations

Minority women with interest and aptitude in science or engineering face special problems since they face barriers related to race and sex in pursuing such careers (Malcolm, et al. 1967). The low expectations and lack of access to quality science and mathematics education which limit choices for American Indian, Black and Hispanic youth affect their participation in science compared to the majority. Expectations about the role of women serve to limit these women further. They are most unlike the image and likely to be overlooked as promising scientists or engineers for this reason.

Although Black women complete high school and attend college at much higher rates than Black men, proportions do not carry over in science and engineering fields. Black women were 11% of all employed women in 1986 but only around 5% of employed women scientists and engineers. On the other hand, Asian women were over 5% of women scientists and engineers (over one-fifth of whom were non U. S. citizens), while only 2% of women in the U. S. workforce were Asian.

American Indian, Black and Hispanic women who were given the opportunity to tell their stories in a 1975 conference on Minority Women in Science recalled stories of misassignment to classes for mentally retarded students by virtue of tests given in English to non-English speakers, of counselors who discouraged their pursuit of science and urged them toward more traditional careers, of peers and family who did not understand their choices. It is not clear how much has changed in the thirteen years since the conference.

Disabled women, like disabled persons in general, face barriers to excellent science education. These barriers may take the form of low expectations of teachers, parents and counselors; denial of access to classes or laboratories; lack of appropriate materials to accommodate their disabilities (e.g. textbooks on ape or raised models); or inappropriate test of their capabilities.

The physical disability becomes the major focus rather than the intellectual capability. In addition, under the guise of protecting a daughter with a physical disability, parents may, inadvertently, delay her gaining independence and limit her participation in path-breaking, non-traditional activities.

When viewed in this manner, it is a wonder that minority and disabled women make it into science or engineering at all.

Life After High School

While the interest of young women in science and engineering is lower than that of young men at grade 10 and at entry into college, the pipeline is, by no means, closed to them. Analysis of High School and Beyond data reveal "dropping back into science" as late as the sophomore year of college. This phenomenon was quite strong among non-traditional science students - women and minorities. Of course, one's ability to "drop back in" will be dependent on whether the appropriate coursework, especially mathematics, was completed in high school. Even the talented women who declare their intention to major in mathematics, science and engineering fields do not all make it to graduation day with degrees in these fields. Neither do the young men, but the losses are greater for the young women.

We can speculate on the causes of the greater losses of women students from the science education pipeline. Most of the reasons have little to do with academic ability, but relate to affective and environment issues. The literature review would lead to discussions of such topics as:

- *Campus climate.* Do women get the idea that they are really wanted in the school, in the department, in the classroom, in the laboratory?

- *Critical mass.* Is there a token presence of women as students as well as faculty or are the numbers significant?

- *Support system.* Are women isolated or made to feel this way? Are they included in the informal networks of students or in constructive mentor relationships with faculty?

- *Confidence in abilities.* Is the college experience affirming for young women? Is there adequate feedback on their performance and their potential compared with other students? Are they encouraged to participate in confidence building activities such as undergraduate research?

When things don't work well, the young men blame the system; the young women blame themselves. They fail to recognize that the problem is not with them.

The Bottom Line

In 1986, Ph.D.'s in mathematics were awarded to 367 U. S. citizens, 298 to men and 69 (about 19%) to women (NRC, 1987). Seven years earlier (1978-79) women earned 41.7% of bachelor's degrees and in 1981-82, 32.2% of master's degrees in mathematics. (Vetter and Babco, 1987). A similar pattern of loss at each succeeding level of the pipeline can be seen for women across science and engineering fields. Perhaps the question is only partly one of *finding* brilliant women, but also of keeping them once found. Science, mathematics and engineering may not be getting their "fair share" of the best and brightest women, but perhaps these fields are getting more than they deserve! While these fields have tremendous intrinsic rewards are the costs of attaining them and working in them made too high for women? Is there a "survival of the fittest" mentality, in science, focused supposedly on weeding out the less able? Are the barriers and screens erected to filter intellectual ability and creativity, and do these work the same for men and women?

The medical profession has recently gone through a self-examination to assess whether the academic filters which have been erected over the years have, in fact, given us the kind of doctors we want, and their conclusion was an emphatic, "no." Too much emphasis was placed on the cognitive aspects, ignoring the personal qualities that separate the healer from the mere technicians.

Do we allow students to choose based on the reality of science-the fun, the excitement of discovery, the mental challenge-or do we ask them, instead, to survive the drudgery with no sense of vision-memorizing interminable lists of terms or dealing with concepts only in the abstracts?

A Plan for Reform

Since there is a system of problems which keep the numbers of women scientists, engineers and mathematicians at reduced levels only a system of solutions spanning across educational levels can be expected to remove the barriers to full participation. The research suggests some of following elements as part of a system of reform.

We must improve the quality of education in science, mathematics and technology which is provided to all students.

Grades K-6

Teachers

- Increase teachers' level of content knowledge and confidence.
- Include in the preservice and inservice education of teachers those specified pedagogical skills known to be associated with equitable practice, such as cooperative learning and team projects, peer tutoring, wait time.
- Stress the need for high levels of expectations for all students.

Curriculum and Instruction

- Increase the number of examples drawn from the experiences which girls more often bring to the classroom.
- Increase the opportunity for hands-on activity in science and mathematics.
- Stress experience with phenomena rather than acquisition of terminology through memorization.
- Increase the coverage of topics in the physical and earth sciences, geometry, estimation, mental arithmetic, probability and statistics, problem identification and formulation.
- Introduce technology as a specific content area.
- Embed research on equitable practice into the curriculum.
- Stress development of higher order skills and relationship of science, technology and mathematics to everyday experiences.

Texts and Other Materials (should reflect criteria specified above)

- Choose materials which show women in active roles in science and mathematics.

Out-of-School

- Specifically encourage girls' participation in science projects.
- Mention a specific interest in science, math and technology to parents in conference, and encourage gifts of books and toys that support this.
- Promote student use of books and television programs on science, mathematics and technology.

Grades 7-9

- Provide teachers with specific strategies for equitable instruction with students of this age group.

- Stress active involvement of students in learning science, mathematics and technology, for example, team projects.

- Assign teams of students to develop projects, especially in the physical sciences. It may be necessary to begin with single sex groupings so that young women are not intimidated by young men.

- Choose topics that cut across/integrate physical and biological sciences and technology, e.g., designing an assistive device for a person with a physical disability, or a space station.

- Encourage young women to take algebra as soon as possible, and to continue taking science and mathematics throughout high school. Especially encourage taking chemistry and physics, the courses which young women tend to actively avoid or, by default, end up not taking.

- Encourage young women's involvement in science projects, especially those that involve the science and mathematics in those activities in which girls may be more involved, e.g. the physics of dance, the mathematics of basketball, kitchen chemistry.

Grades 10-12 (In addition to all of the above)

- Give female and male students feedback on their performance and potential. Especially, reach out to and encourage non-traditional students.

- Stress the usefulness of science, mathematics and technology for everyday life and the relationship of studying these fields to future careers.

- Encourage the most talented students and those with strong potential to take advantage of summer, after school or Saturday programs that support their science, mathematics and technology learning. Be sure to include female students.

College

- Provide a support structure for young women majoring in non-traditional fields, including (but not limited to) recruitment, orientation to the major and to campus life, bridge programs, seminars that deal specifically with the potential conflict of career and family, counseling.

- Provide opportunity for early involvement in research as an undergraduate. Especially, target those able women who may not accurately assess their own potential for graduate study.
- Encourage summer employment/internships that will allow students to see what kind of work scientists really do.
- Address the problem of college level science, mathematics and engineering instruction. Provide specific skills or teaching techniques to improve undergraduate instruction.

Graduate and Professional

- By junior year in college, assist students in negotiating the graduate school experience by specific counseling on choosing a mentor, choosing a graduate program, the expectations of a graduate student, financing graduate education, etc.
- Examine each list of nominations for awards, fellowships, special research experiences, to make sure that qualified females have not been overlooked.
- Faculty must give regular feedback and encouragement to female graduate students.
- Faculty must not tolerate sexist remarks or behavior from students and must challenge such from other faculty.
- Support reasonable provisions for dependent care.
- Support flexible schedules for tenure review, to accommodate tenure line faculty who may become disabled, who are injured in an accident or who may face pressing family responsibilities such as illness of dependent parents, children or other life crises.

This list is not intended to be exhaustive, merely suggestive of the type of systematic change which needs to be considered by the community of science, mathematics and engineering-fields facing shortage, and competition for talent from many other areas. Academic science, in particular, may find it hard to compete with industry in terms of salaries and benefits.

We can no longer afford the "weeding" that we have been doing. We must be able to draw on the talent from among that two-thirds of the pool which has not been cultivated for science and engineering.

Our future depends on our ability to rise to this challenge.

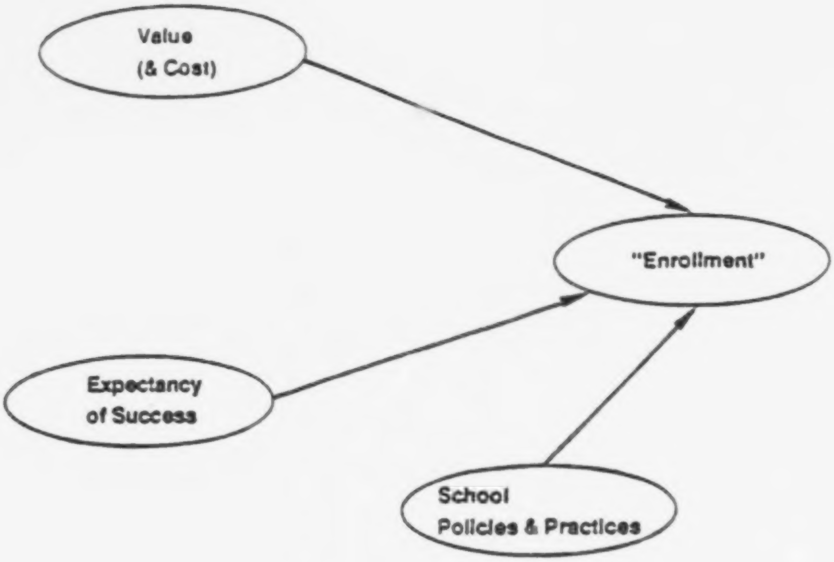
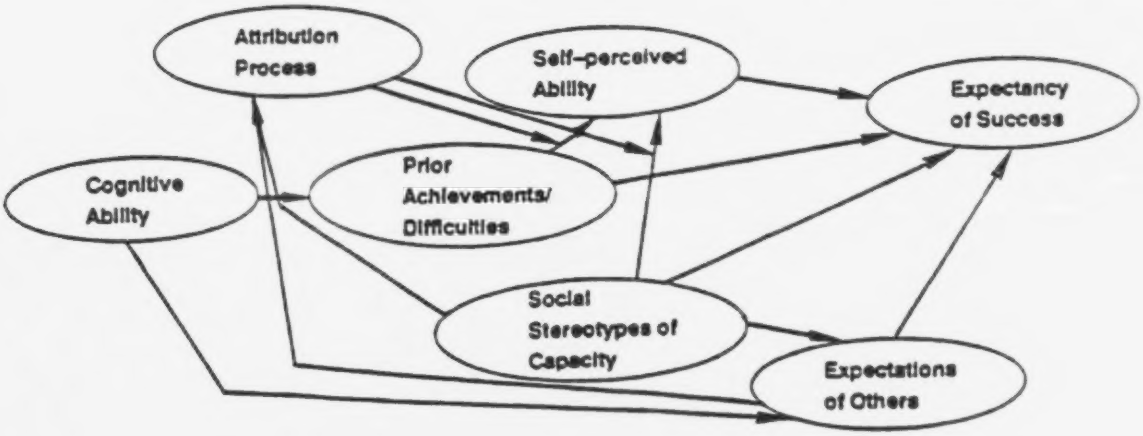

Value
(& Cost)
"Enrollment"
Expectancy
of Success
School
Policies & Practices

Figure 1 - Core of the Model


Attribution
Process
Self-perceived
Ability
Expectancy
of Success
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Social
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of Others

Figure 2 - Influences on expectancy

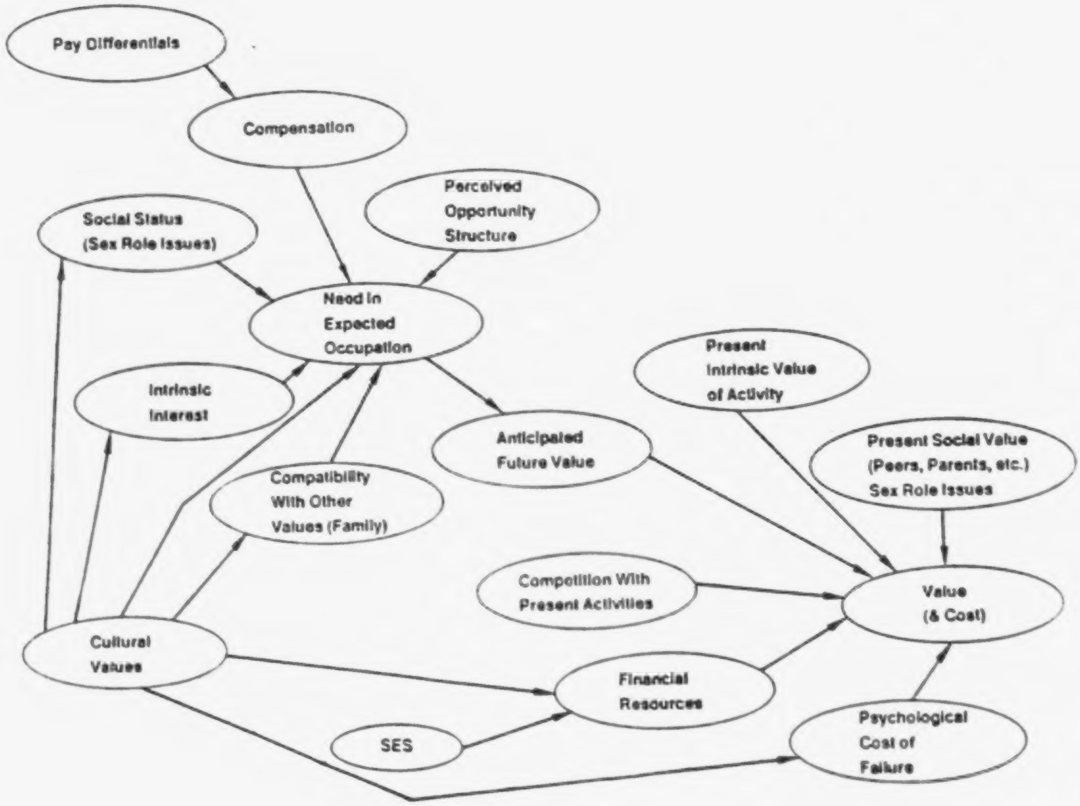
Pay Differentials
Compensation
Perceived Opportunity Structure
Social Status (Sex Role Issues)
Need In Expected Occupation
Intrinsic Interest
Present Intrinsic Value of Activity
Anticipated Future Value
Present Social Value (Peers, Parents, etc.) Sex Role Issues
Compatibility With Other Values (Family)
Competition With Present Activities
Value (& Cost)
Cultural Values
Financial Resources
SES
Psychological Cost of Failure

Figure 3 - Influences on value

Discussant Reaction:
Brilliant Women for Science, Mathematics, and Engineering: Getting More Than We Deserve?

Carolyn M. Callahan

Shirley Malcolm asks the question, "Are we getting more than we deserve?" Her paper and the extensive study of the factors which have inhibited the achievement of females in mathematics, science, and technology are testimony to an emphatic "Yes" as an answer. The degree to which women have elected careers in mathematics, science, and technology and have managed to accomplish their goals is testimony to extraordinary efforts on the part of those women to overcome the stereotypes, biases, and cultural influences which work against such accomplishment and to those parents, friends, counselors, mentors, and programs that have provided the necessary support to these women.

Further, the categories of factors which Malcolm provides to account for differential achievement are useful in organizing our thinking about ways to modify those circumstances. I would, however, break out the "out-of-school experiences which influence test scores" to coincide with the influences of Chipman's model and to include factors which specifically influence the attribution process, the development of self-esteem, values--social, cultural, and intrinsic--and perceived ability in mathematics and science. That is, I would suggest we add these other categories which may not be completely independent categories, but which may help us ensure full attention to all relevant factors.

- The experiences which students have in school--not in class (in counseling situations, in social groups, in athletic programs, etc.)
- The attitudes and expectations of significant others

Although the last category will certainly be influential in creating experiences in and out of school, it would seem necessary to stress their importance by creating a specific category.

Another factor which seems critical for our consideration is the sex-role stereotyping of science and mathematics-related careers. Farmer (1987) has demonstrated that young women who are at the age of deciding on careers (late adolescence) most value personal interactions and have very strong social values (wishing to make a significant contribution to society). These same women perceive science and mathematics-related careers to be of a nature where all or nearly all work is individual, requiring social isolation both because of the setting and the demands that one work endless hours and to be so theoretical and abstract as to be of no practical value to society. Because they thus perceive that they will be unable to have meaningful relationships with people because of the work setting and the demands and that the work has no socially redeeming features, they reject those careers as options. She suggests that one of our missions must be to educate young women on the real variety possible in careers in these fields.

Eccles' research (Eccles, Adler, and Meece, 1984) also leads us to the importance of the family and of society in general in the development of young women's self-esteem, aspirations, and ultimate achievement. Further, Betz and Fitzgerald (1987) have included working mother (role model), supportive father, highly educated parents, female role models and androgynous upbringing, liberated sex role values, androgynous personality, high self-esteems, and strong academic self-concept (These latter two variables have been demonstrated as related to parent perceptions among gifted females.) as factors, among others which are facilitative of women's non-traditional career choice.

Malcolm suggests that one strategy for improving the quality of education in science, mathematics, and engineering is to introduce science as a specific content area. While that is a curriculum decision which seems warranted in general in light of current developments, it is important to examine the ways in which such a decision may or may not enhance the development of interests and achievements of females. I will use the computer and computer skills as an example since we have had some experience with this technology. Unfortunately, the rapid introduction of computers into education without careful consideration of instructional strategies and the implications of choice on what and how to teach that technology may have contributed to *increased* differences in male and female achievements and attitudes. For example, Sanders and Stone in *The Neuter Computer* (1986) point out that there is a great gender gap in the use of computers in school. Among citations too numerous to go into here, they note that in one study, only one-fourth of those junior high and middle school students who used computers on an optional basis were females; in another study 40 percent of high school boys used the computer during free periods while only 8 percent of females did; and a survey of high school programming courses in California, Maryland, and Michigan showed that boys outnumbered girls two to one. Many of the factors which they believe contribute to that gap are similar to those which are commonly addressed in the literature on females in math and science. Among these factors are:

> *Computer users:* Girls observe that most computer users are male--in their schools, in the home, and in the media.
>
> *Mathematics association:* Because computers are associated historically with number crunching; the fact that they are used more often in math-related courses; and the fact that math teachers are most frequently the computer teachers; females associate computers with math and masculinity.
>
> *Machines:* Computers are perceived as machines (and often introduced as machines first), and because females are not socialized to be comfortable with machines, they are uncomfortable using computers.
>
> *Software orientations:* Much software--both educational and recreational--is male-oriented with orientations toward war, death, and destruction, or sports. For example, how many software programs give feedback by having something explode, having a missile hit a target having, a football go over a post, etc.
>
> *Language:* Does computer "jock" suggest anything feminine to you?
>
> *Male assertiveness in capturing computer time:* Boys, in their enthusiasm for computers, often sign up first for available time slots or will quickly run to and claim computer space while females, who are taught to be polite and wait their turn, are left out.

> *Competing interests*: Desire for social content is a strong drive in the development of female adolescents, and young girls are not as likely to want to engage in the solitary activities often assigned as computer tasks.

My question is this, when we introduce computers or any other technology, have we given adequate thought to the existing differences in the ways young girls may be seeing the technology? Do we have to take the computer apart and learn all of its parts on the first day? Is that most likely to generate an interest by females? (By the way, I am certainly *not* suggesting that we be condescending or diminish the value of computers to females by introducing it as a machine that will store recipes either!) It seems as if we have not adequately addressed these questions; rather, we have introduced a new technology in such a way as to provide further differentiation.

It also seems important to include a revision of textbooks at every level if we hope to impact the female student and her interests and aspirations. The current texts are written by men with examples heavily slanted toward the male experience and with an implicit assumption that whoever has chosen to take the course brings an intrinsic motivation to learn whatever information, skills, concepts, etc. the books contain. The current texts do little to demonstrate the ways in which the knowledge of these disciplines contribute to the world, providing only token attention to the functions of science, mathematics, and technology in the everyday world or in careers. (My husband still asks me why he had to take trigonometry. He says he has rarely had to figure out the height of a building by measuring the height of a tree and the shadows of the building and the tree.)

It is also crucial that we not only examine content and teaching strategies such as hands-on versus textbook learning, but also that we look at some of the other more subtle ways in which we influence the attitudes of females toward themselves and toward science, mathematics, and technology. For example, under certain conditions, females have been shown to demonstrate significantly lower expectancies for success and consequently lower achievement when a task had a perceived "masculine" orientation even if there was no real difference in ability to achieve on the task. For example, Deaux and Farris (1977) reported that when an anagrams task was labeled masculine, women's performance expectancies were lower than men's; however, when that same task was presented as feminine, the performance *expectancies* were equal. House (1974) found that when tasks were presented under competitive conditions, females' expectancies for success were lower than those of females working alone or males working under either condition. All of this has led me to agree with Brophy (1985) that it is not enough to treat male and female students equally if gender differences are to be eliminated. Different, rather than identical, treatments may be necessary.

Finally, a thorough and complete assessment of all the factors which influence the choices made by young women necessitates an expansion of the definition of "environment" to include the scientific environment, the community of scientists, and even the cultural definitions of science. Evelyn Fox Keller has raised some intriguing questions in the book *Reflections on Gender and Science* which merit the attention of both scientists and educators. At a very fundamental level, this mathematical biophysicist questions the labeling of one aspect of experience as feminine and another as masculine. Noting the popular mythology of science is to cast objectivity, reason, mind, and therefore, science as masculine; she points to the shortcomings of this image both to the development of the discipline of science and to the attraction of women to science. She notes:

> To both scientists and their public, scientific thought is male thought in ways that painting and writing--also performed by men--have never been . . . objectivity itself is an ideal that has a long history of identification with masculinity. The fact that the scientific population is, even now, a population that is overwhelmingly male, is itself a consequence rather than a cause of the attribution of masculinity to scientific thought . . . Now that the women's movement has made such naked assertions [about the fact that women cannot be good scientists] offensive, open acknowledgement of the continuing belief in the intrinsic masculinity of scientific thought has become less fashionable. It continues, however, to find daily expression in the language and metaphors we use to describe science. When we dub the objective sciences "hard" as opposed to the softer (that is, more subjective) branches of knowledge, we implicitly invoke a sexual metaphor, in which "hard" is of course masculine and "soft" feminine. . . . A woman thinking scientifically or objectively is thinking "like a man" (pp. 77-78).

Keller is quick to point out that success in the scientific world for the time being will require the assumption of the roles, the attitudes and the values currently associated with the profession. However, her belief is that scientists will come to recognize the degree to which their "objective beliefs" are really biased and her hope is that ultimately science will not be gender stereotyped in its thinking or in the public's perceptions. We can only hope that the same can happen in mathematics and engineering.

Unfortunately, we have only scratched the surface of a complex issue here. We have not dealt with the media, the toys we provide as parents and teachers, the subtleties of our culture, and the messages which present conflict and unresolved issues to young women who are making decisions about their careers. However, any steps we can begin to take will make us better off tomorrow than we are today.

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Discussant Reaction: Bright Girls in Math and Engineering

Nicholas Colangelo

This is going to be hard because what I want to do is make some comments that will not be repetitive of what Dr. Malcolm and Dr. Callahan have said. They have covered many things that I have found in my own research and my own work with gifted girls and with gifted boys. So by not mentioning certain things, I am actually confirming them. I will try to get to some other points that I think would be of interest.

First of all, something that has been glossed over so far: It was mentioned fleetingly . . . let me go back to the Maccoby and Jacklin study of 1974 where in essence their literature review said that somehow or another boys come out higher in verbal areas. In my neighborhood, what that comes down to is that boys can put two and two together, and girls can read the handwriting on the wall. That kind of thinking has permeated the way we think about boys and girls. Anyone who does not fit that mold we usually think of as an "exception" rather than the rule. Now, there is some evidence which is pretty clear and hard to ignore. I do research with ACT (American College Testing), and I'll share some of that research with you. Certain trends do come out by gender; let's take a look at the reading and verbal scores.

First of all, there is an excellent longitudinal study done by David Martin and H. D. Hoover called "Sex Differences in Educational Achievement: A Longitudinal Study" (1987), reported in the *Journal of Early Adolescence*. The article reviews a number of studies indicating that across the nation and for many years, little girls have beaten little boys in measures of reading and verbal skills. As a nation, this fact doesn't get our attention at all. Everyone says, "So what?" And the magnitude of what girls have over boys is much higher than the magnitudes that are reported in terms of boys' mathematics and quantitative reasoning. This is important because we are not dealing with just gender differences, but with things we choose to focus on and things we don't. There are males who have majored in English, decided to be English professors or English teachers. Most of the time, if a young man is going to go into English or wants to teach English, usually the deterrent is that there aren't many jobs in the field or that there isn't much money associated with the area. No one ever implies that males aren't quite as good as females in English and perhaps they shouldn't get into something they can't really do. It's not even thought of. Let me make the other point. When girls think about a mathematics or science field there is an innuendo that it really isn't their turf. They must be either pretty exceptional or they have some nerve. And yet we don't do this to males. We don't say, "Are you going to go into something that requires verbal skills?" We don't imply "Are you sure you can tackle something that is not male turf?" We don't even think of it that way. We assume that if you, as a male, make that decision, then you've got enough skills to succeed. But we don't assume the same thing with girls. Another point--somehow our society has decided that it is more important to be good in mathematics and science than in reading and verbal skills. How that came about is a bit more that I can put my finger on, but I think it's interesting that the area that girls are strongest in is not valued. It could be coincidence; it might not be.

A third issue: Dr. Malcolm talked about course-taking. Let me give you some other information about course-taking practices. An ACT research report by Lange, Engen, and Maxey (1987) looked at the relationship between ACT scores and course-work. ACT tests are supposedly more curriculum-based than SAT (Student Aptitude Test) so that the kinds of courses that a student takes should have some impact on the scores on the ACT. What they found is that there is a correlation between course-taking and ACT scores, but what is especially interesting is that the correlation is really only strong with mathematics and science courses, but is not very strong with English or Social Studies. What this suggests is that if you don't learn mathematics in a formal mathematics course, you are not going to learn it because it's not the kind of thing that the kids down the street talk about. If you don't learn science in a formal science-type course, you probably won't pick it up. Whereas in English, and especially in Social Studies, there are things you can learn by watching television, by chatting with others, or by reading *Time* magazine. You can pick up enough information to help you score well on ACTs. So when we talk about coursetaking, we have to be more specific than just coursetaking; it is specifically mathematics and science curriculum that has a greater bearing on levels of achievement. Dr. Malcolm and the ACT report provide similar evidence indicating that girls take significantly fewer mathematics and science courses at the advanced level. In order to score very high on the ACT, it is necessary to go beyond the basic introductory mathematics and science courses. I think that, as counselors, as educators, every time we allow a girl to easily opt out of mathematics and science classes, we are helping that girl close a door on her future; the same thing is true with boys.

Dr. Malcolm also brought up in her paper that many students do not realize the kinds of doors that will close on them in college if they have weak mathematics or science backgrounds. They are often told that they can go back and make up courses that they missed. In reality, life doesn't work that way. A lot of kids have fooled themselves by thinking they can go to college and be anything that they want to be. That is quite untrue and it's becoming less true. Many state schools have what is referred to as a "semi-open door" policy, which means that any state resident in the top half of his or her class can attend a state university. However, what the brochures don't say is that you have to have certain averages to get into specific majors. The front door is fairly open but all the little doors inside aren't, and so many of the students who get into the State University cannot get into the specific field they anticipated they were going to get into, and they end up in a holding pattern. The holding pattern is a euphemism for a General Studies or Liberal Arts program, and the discipline that was supposed to enhance people's thinking has become something of a dumping ground because all of the other disciplines have become more selective. Those are the kinds of things that I think we have to be very careful of, because those doors started shutting several years before these students went to college.

A piece of research that needs to be talked about is the Camilla Benbow and Julian Stanley research report in 1980 that stated: 1) That at the highest level, boys significantly out-score girls on SAT tests of mathematical reasoning; 2) That when you control for coursework, boys still out-score girls at the high school level in mathematics reasoning when using the SAT. So their comment, as reported in *Science*, was that coursework is not a legitimate explanation for differences in mathematics reasoning by gender at high levels. What they said is that you have to take a look at perhaps others things, perhaps socialization and endogenous variables. That causes quite a furor because it does begin to sound like "inherent ability," and whenever we are going to talk about ethnicity, whenever we're going to talk about gender, people don't want to hear that heredity may be a significant variable. I believe there is a portion of the population who believe there are genetic or biological differences when it comes to mathematics ability. A study such as Benbow and Stanley will receive considerable "press." The results even appeared in the *New York Times* and *Science*.

I would like to make a comment from Jacquelynne Eccles. She reported in the *Educational Researcher* (June/July, 1986) that one of the issues young girls are faced with if they decide to go into mathematics or engineering is that it is not a personal choice anymore. These girls are representing all womanhood, and I think that puts a lot more pressure on career decisions. Eccles believes that one of the reasons why a lot of high ability girls deliberately do not go into math or engineering is that they simply prefer other areas. Even though they are capable, they would just as soon not go into mathematics and science because they are positively attracted to something else. One of the things we have to be careful of whenever our microscope is on a group (e.g, gifted girls) is to respect a legitimate choice by girls who have the ability to go into mathematics and science but choose not to, rather than making the accusation that they are "copping-out." These girls are in a difficult position. I think the day will come that girls, like boys, will make decisions on the basis of what they want to do. Right now, promising girls in mathematics and science do not have that luxury.

Another point from Helen Farmer (1987): She says that when a society doesn't support mathematics and science for girls, as Dr. Malcolm's paper documents, then the roles of parents and teachers are much more important. Parents and teachers are more influential in helping girls gifted in mathematics and science make decisions than they are in helping boys, because there is more risk-taking involved for girls. And when there is more risk-taking, mom and dad's "Hey, you can do it" is a lot more powerful than when the child chooses a field that is appropriate or acceptable.

There was a time in this country when for a young woman to go to law school was a major accomplishment. Or to go to medical school. Today, it's not the revolutionary move for women to go to law school or medical school, but it is to go into engineering. If I may digress with a comment about medical school: Barbara Kerr and I (in press) have been doing some studies with ACT scores and preferences for majors and careers. It's interesting that even though the number of young women going into medicine is fairly large, their distribution among medical specialties is very uneven. There seem to be certain areas of medicine that they go towards and others areas that they don't. Somehow or another, as soon as women move in on something, the men leave. Most of the women going into medicine go into Pediatrics, OB-GYN, Family Practice. They do not go into surgery. You will find that there are real gender differences within specific areas of the medical profession.

The same thing can be said for the sciences. What Dr. Kerr and I found was that high-ability girls prefer biological sciences to the physical sciences. So we can't even talk about science in general; there seem to be tracks within science.

That seems to me the more subtle, the more destructive element, because sometimes, globally, it seems like things are equitable, but when you look closely, there are little trenches within.

I am going to go back to something that Dr. Callahan said about computers. I don't fully agree that what's happened is that males have taken to computers and females have not. What really has happened is that females are seen as good at the word processors. That's become their turf within the computer realm. Males use the computer as a computer and females use it as an "advanced" typewriter.

I have a couple of comments that I would like to make about ability and effort and this is somewhat of a speculation. When it comes to ability and effort, I think that, as a nation, we believe that mathematics and science are more tied to ability and English and Social Studies are more tied to effort. Most times we will not discourage people from going into the Social Sciences because of poor test scores. We will say things like, "Hey, if you're talking about majoring in Chemistry, you've got to be bright." But, if we are talking about History, we say, "Well, if you're willing to work hard, you can make it." So it's not just a matter of ability and effort per se, we even have certain preconceived notions that most anybody can probably be a Social Studies teacher, but you've got to be intellectually gifted to make it in math. I think these are the beliefs and messages we really need to take a look at in terms of ability and effort.

I want to share with you some findings from the ACT studies that I have been doing with Barbara Kerr. We have done a study of almost 800,000 students who took the ACT in 1985-86. We wanted to take a look at the kinds of kids who typically go to college (the upper 80th percentile); the moderately talented (the top 5 percent); what we call the highly talented (the top 1 percent). First of all, engineering is definitely the drug of choice among talented kids in high school in terms of a college major. While engineering is definitely the top choice, it is overwhelmingly chosen by talented boys compared to talented girls. Now if a female scores in the 99th percentile, it's the same as if a male scores in the 99th percentile. So ability cannot account for the difference in major and career preference. Thirty-two percent of the 99th percentile boys and 9.9 percent of the girls said that they wanted to become engineers. What we cannot figure out is why so few of the 9.9 percent of the girls of the highly talented actually pursue engineering. The boys who threaten to be engineers, for the most part, carry out that threat. The girls who threaten, don't. That's what concerns us. What happens between a young girl with ability saying, "This is what I'm interested in," and failing to pursue it? That's the point at which I think many of the issues raised by Dr. Malcolm come to the forefront.

The other part of the ACT study has to do with science. Biological sciences: at the top 1 percentile, 14.1 percent of the females are interested in biological sciences, and 3.9 percent of the males. When it comes to physical sciences, of students in the top 1 percentile: males, 11.1 percent; females, .8 percent. You see the segregation by gender even in the kinds of sciences. It has nothing to do with ability because, again, you are talking about the top 1 percent of both males and females.

Interestingly, talented girls are more interested in pursuing a mathematics career than are talented boys (according to our data). At the 95th percentile, 2.4 percent of the females versus 1.7 percent of the males choose math as the preferred career. At the 99th percentile, it's 5.6 percent of the females versus 4.4 percent of the males. In kids with that kind of ability, girls are more interested in mathematics majors and careers than boys but someplace along the line, they don't live out the decision the way that boys do.

I would like to share with you how talented youngsters rate education as a potential major and career choice. The higher the score on the ACT, the lower the desire to pursue a career in education. That had better start concerning us as a nation. At one time, because we were such an effective sexist and racist nation, we could rely on a steady supply of the brightest women and minorities to be in teaching. That steady supply is no longer viable. Only 4.8 percent of the kids at the 99th percentile were interested in pursuing education as a future. From our data, it seems the great portion of our future teachers is going to come from those who score below the 80th percentile. That's going to have some ramifications in terms of the future of our educational system.

I want to say a couple of things about counseling. Pat Casserly (1979) did an interesting study for Educational Testing Service (ETS) about high-ability girls in mathematics and science, and counseling. One of the things she found was that school counselors in her sample actually discouraged high-ability girls from pursuing majors and careers in mathematics and science. This was by both male and female counselors. Casserly offered two reasons for the findings: One was that the counselors themselves feared mathematics and science and passed that fear to the girls. Two was that many of the counselors felt that it was difficult enough for boys to get jobs in these areas and that girls would just cause more problems by competing with the main breadwinner. Look at the kinds of subtle and overt messages that bright girls were getting.

When I was at Madison, Wisconsin, we observed counseling sessions with gifted boys and girls and most of these sessions were about career and college choices. One of the things we observed in a small sample was that often when bright girls said that they wanted a career that would take considerable graduate work like law and medicine, the counselors would say, "Have you thought about how this fits in with having a family?" Now that is a legitimate question because it's something that they should think about. However, it was never brought up with gifted boys. If it is a legitimate question, then boys ought to think about what their career plans mean in terms of family. The fact that it was brought up only with girls suggests the implied message, "You may be doing something that is less than wonderful."

Bright girls in our society are being subtly and overtly dissuaded from thinking about careers in mathematics and engineering. This form of sexism is not only destructive to the youngster, but destructive to the entire society. I see that a major purpose of this conference is for us to generate ways to combat this sexism.

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BETTER MEASURES: DEVELOPING MORE MINORITY MATHEMATICIANS AND SCIENTISTS

Judith Berry Griffin

The relatively small number of minorities pursuing careers in science, mathematics, engineering and other "high-tech" fields has been well-documented over many years. This continued (and increasing) underrepresentation is of great concern to educational practitioners for several reasons. We at A Better Chance, Inc. (ABC) view competence in mathematics and science as controlling current and, more importantly, future career opportunities. We recognize that increased career opportunities will help America remain competitive in an increasingly internationally-oriented society where technological skill is the major currency. And we acknowledge and understand the population changes projected to begin their impact in the United States within the next ten years--changes which will bring a rapid and significant increase in the numbers of minority workers.

These facts are even more sobering when viewed against a national backdrop. Here we see increasingly common incidents of racial violence. There we find our inner cities, with distressed schools and inadequate housing, barely containing a burgeoning underclass without jobs, without money, without hope for a better future. And over all has settled a treacherous miasma of personal and organizational greed and selfishness, making attention to equity issues of disinterest to many and appropriate remediation difficult to shape. For educational practitioners, among others, concern has given way to anxiety that America is on the verge of becoming a second-rate, ungovernable society.

Under these grim conditions, new and innovative methods of identifying, recruiting and adequately educating all minority young people, and stimulating interest in science-mathematics endeavors, must be sought and supported.

The work of A Better Chance has long been based on the hypothesis that there exists a pool of broadly talented minority students whose abilities are best identified by criteria in addition to the quantitative measures traditionally employed for student assessment. In the process of confirming this hypothesis, we have found that certain factors have a probable positive effect in encouraging a good number of these students to select courses of study (and eventually careers) related to mathematics and science. This paper will document the validity of these observations.

Many reasons have been promulgated for the failure of minorities to pursue math-science careers in greater numbers. Among them have been: socioeconomic background; academic background; student adjustment and integration into campus life; institutional characteristics; mentors; and cultural orientation toward competition and success.[1] Also noted have been inadequate financial aid; low expectations for minority student achievement; and the lack of well-organized and aggressive programs for recruitment, selection and retention.[2]

During the past 15 years a number of special programs have been developed to stimulate and support minority student interest in math-science education. These programs have been particularly visible in the field of engineering, from which such efforts were first mounted. Although it is difficult to adequately examine their success, since information is limited and effective methods of assessment and comparisons have not been developed, some measurable results have been produced. We know, for example, that the number of minority graduates from these programs increased tenfold between 1971 and 1986,[3] and the number of blacks among all students pursuing engineering degrees rose from 4.5 percent to 7.5 percent in one five year span (1973 to 1978)[4]. By 1985, blacks were earning nearly three times as many baccalaureate degrees in engineering as they had ten years earlier.[5]

However, these modest gains are overwhelmed by the more pessimistic figures describing actual movement of minorities up the science-mathematics academic ladder and into the working world. The 1980 statistics produced by the National Science Foundation show that blacks remained greatly underrepresented in the science-engineering work force, constituting 1.6 percent of that group, although they represented 7 percent of all professional and related workers (NSF, 1982). Moreover, graduate enrollment figures show that only about half as many blacks as whites progress from baccalaureate to master's level graduate studies in these fields (similar figures apply to Hispanic and Native American students). In 1985, only 64 American Blacks earned doctorates in physical science, mathematical or computer science, or engineering, as compared to 118 American Hispanics, 522 Asian Americans, and 3,031 foreign students.[6] And the numbers of black students enrolling in and graduating from colleges and universities has actually decreased over the past several years.

The available evidence supports two conclusions. First, despite the small gains made by minority students in entering mathematics-science-engineering fields of study, they continue to be severely and increasingly underrepresented in these areas. Second, retention of minority students in these fields becomes even more problematic as these students continue through the education pipeline. Attempts to ameliorate the first condition, then, must be strongly supported by an examination and understanding of the probable causes of the second.

The opportunity to study this problem in a unique way has recently become possible through the documentation of the efforts of A Better Chance, Inc. (ABC). For 25 years this Boston-based national talent search and referral agency has been scouting the nation's inner cities, seeking out academically able minority students and placing them in some of the country's most selective and prestigious independent preparatory schools, and a few select public secondary schools. ABC's alumni (those graduating from secondary school between 1966 and 1987) and its enrolled students (those currently attending grades 7 through 12) together number some 74,000. The alumni group, most of whose academic and social environments have been dramatically altered by their association with ABC, is highly mobile, as its members pursue many differing career and educational options.

The pilot program that was to become A Better Chance came into existence in 1963 as a partnership between Dartmouth College and a group composed of 23 heads of the country's leading independent boarding schools. Officials at Dartmouth were concerned with increasing the college's enrollment of the college's black students. They proposed to do so by means of "Project ABC," through which high school students with high academic potential would be identified and offered a summer of intensive academic work, thus paving the way for college entrance and easing what would undoubtedly be a difficult academic and social transition. The group of school heads had meanwhile initiated a similar effort to identify and recruit black students through a project called the "Independent Schools Talent Search" (ISTS). Joining forces, projects ABC and ISTS worked out a plan to enroll 50 boys in the cooperating prep schools, contingent upon their successful completion of Project ABC on the Dartmouth campus. ABC and ISTS eventually merged to become A Better Chance, Inc.

Funding for this joint venture was initially obtained both from private sources and the Federal government's anti-poverty program. A simply worded mission statement was adopted: to "substantially increase the number of well-educated minority people who can assume positions of responsibility and leadership in American society." Through the years this goal has remained essentially constant, although varying methods of effecting it have been employed by ABC.

Significant changes took place as the program evolved. Girls' boarding schools were quickly added to the client list, then day schools. In the late 1960's "Public School Programs" (PSPs) were introduced. Funded and organized by volunteers who live in the mostly suburban communities which house the programs, the PSPs operate on the boarding school concept. ABC students live with Resident Directors in a community-leased or community-purchased "ABC house" and are thereby eligible to attend the local high school. The students are supported by local volunteer "host families." Among ABC's present population 161 member schools are 23 PSPs, enrolling from six to twelve students each.

Since major student recruitment activity takes place in some of the nation's most distressed inner city neighborhoods, e.g., Harlem, the South Bronx, and Brooklyn, New York, and comparable neighborhoods in such cities as Chicago, Detroit, Philadelphia, Newark, Los Angeles and Atlanta), the majority of ABC students require full-need scholarships at the accepting schools. Partial scholarship assistance for each student was available until the early 1980's through certain federally funded programs. However, the last of these grants was exhausted in 1980. Since then, funding for ABC's activities has been secured through private sources--gifts and grants from corporations, foundations, and individuals (including alumni). Member schools absorb the necessary tuition costs for the students.

The basic activity of A Better Chance is identifying, recruiting, matching and referring mostly ninth and tenth grade students to its school clientele, and providing limited student support services. ABC's work is made possible by an energetic and enthusiastic network of some 3,000 volunteers across the country, who, among other activities, distribute 15,000 informational application packets each fall.

For students, the selection process begins with the submission of a completed application, which requests family and personal information, official school transcripts, and recommendations from "sending" teachers, guidance counselors or principals. The process also requires applicants to write essays, to be interviewed, and to take the Secondary School Admissions Test (SSAT).

Of the applications returned and initially processed by the ABC staff, approximately 1,300 are selected for close scrutiny. These 1,300 are eventually reduced to approximately 700 "active" applicants, who form the pool from which approximately 325 students will finally win placement.

At the heart of the process is the work of the ABC "referral committee", which considers all applicant information, member school characteristics, successes of previous students and other factors. The committee then carefully selects two or more schools at which it believes each applicant may find a comfortable "fit". Student application materials are forwarded to the selected schools, whose admission officials decide whether or not to admit each applicant. Applicants not admitted may or may not be referred by ABC to additional schools.

Once students matriculate, specific student support is offered through ongoing direct student contact and through contact with school-assigned "ABC Coordinators" at each member independent institution and with PSP Resident Directors. Students are more generally supported by means of such activities as elective summer enrichment programs, and a competitive program of awards for academic excellence, for leadership, and for perseverance. College counseling is provided for juniors and seniors. Attendance at a one or two day prematriculation program is required, and individual counsel with students, parents and school faculty can also be provided as needed.

A Better Chance has maintained some contact with its alumni through the years, but has increasingly come to recognize the need to develop and maintain a data base of information on its graduates and their post-high school progress. Because detailed information on this type of population is not available elsewhere, such a data base would be highly valuable in addressing, among other questions, the concerns ABC and many other groups have had about the relatively small numbers of minorities entering science, mathematics and the technical fields in general. These dual concerns were combined in a proposal which resulted in a grant from the Ford Foundation to survey ABC alumni in order to: 1) improve ABC's data base by updating its alumni files, and 2) gain information useful in determining factors which might contribute to enlarging the pool of minority group men and women who choose to enter mathematics and science-related careers.

The resulting extensive study of ABC alumni was conducted during 1982 and 1983 by Sylvia T. Johnson, Professor of Educational Research Methodology and Statistics at Howard University, with the assistance of Research Associate Sukai E. Prom-Jackson. Its primary objective was "to investigate the process of career choice among ABC graduates, with particular emphasis on the factors affecting the choice or rejection of careers in science and mathematics."[7]

In 1987 a second, less extensive study of ABC graduates was also conducted by Dr. Johnson, this time with the assistance of Michael E. Reed, who was at the time Director of Programs at A Better Chance. With funding provided by the Andrew Mellon Foundation, this study undertook the investigation of "the adequacy of equitably predicting the achievement of ABC-identified students through the use of currently standard testing technology."[8]

It is our belief that an examination of the results of both of these studies can help illuminate the problems associated with the identification of talented minority youth and their education and retention in math-science fields. We additionally believe that, while further documentation is certainly appropriate, these studies' findings to date clearly commend a specific course of action.

The Ford Study:
Science and Mathematics Career Choice Among Talented Minority Graduates of A Better Chance, Inc.

Background and Rationale

According to Dr. Johnson:

> Many studies have documented the fact that relatively few Black, Hispanic and American Indian students take advanced high school courses in Mathematics and science. Most then conclude that this is a major reason for the low proportions of these groups found both among college majors in mathematics and science, and among related professional fields.[9]

She further states:

> What causes the low level of participation in advanced high school courses in mathematics among Black and Hispanic youth? An extensive set of studies documents the roles of several factors, including aptitude, achievement, personal interests, career interests and aspirations, perceived utility of mathematics to career interests, sufficiency of career information, attitudes toward science and mathematics, the high school curriculum and graduation requirements, the nature of guidance and counseling services, family support, social support, and the availability of role models in science and mathematics-related fields . . . Missing from these studies is an investigation of college major and career choice among minority students with strong general academic preparation in mathematics, science, English and other areas.[10]

The opportunity, then, to investigate the incidence of these career choices among ABC students, who have both taken these advanced courses and have been well prepared to do so, is particularly inviting.

Methodology

To investigate the process of career choice it was necessary to gather information regarding these young people in a variety of areas. The areas selected included high school and college experience, family background, personality dynamics and work orientation, as well as specific information on current and planned vocational choices at several stages, and the reasons for these choices.

A lengthy and detailed survey instrument was constructed to provide basic descriptive information on the population to be studied and was mailed to all ABC graduates with known addresses. Follow-up communications were also utilized over several weeks. The 813 respondents who completed surveys (25 percent of the number mailed) constituted the sample population. Since hundreds of surveys proved undeliverable the return rate is assumed to approximate 40 percent of the material actually received by alumni.

The sample group turned out to be 57 percent male and 43 percent female; 76 percent Black, 11 percent Hispanic, 3 percent Native American, 3 percent Asian, and 7 percent unidentified or "other" races. It included graduates spread across all ABC's years of operation.

The survey instrument, which was completed anonymously, examined high school and college characteristics, services, sources of funds, student experiences and performance, self-perceived ability, family background, experiences and values, personal values, reasons for career choice, job-related values and job satisfaction, and personality dynamics and work orientation. These factors were examined to determine their relationship to two primary variables:

- Choice of advanced science/mathematics courses in high school
- Choice of a science/mathematics career.

Findings

The findings revealed that was the best predictors of the taking of advanced science and mathematics courses in high school were the following:

- The self-perception of ability in science and mathematics
- The perception of the high school mathematics curriculum
- The identification of a high school mathematics or science teacher as the most influential person in one's school experience
- The academic atmosphere of the high school

Among graduates who had taken advanced science and mathematics in high school, the primary reasons given were the following:

- Interest
- The challenge of the subject
- Perceived ability

Graduates who had not taken advanced science and mathematics reported that they were more interested in social sciences, but they did not, in general, indicate a lack of interest in science or mathematics.

When the choice of a career in science or mathematics was the criterion, 34 significant predictors were identified. The major predictors were as followed:

- Self-perception of ability in science and mathematics
- Enrollment in advanced mathematics courses in high school
- The influence of a science or mathematics teacher

- The perception of the high school science and mathematics curriculum

Graduates who had high self-perceived ability in social sciences tended not to choose science-mathematics careers.

Personal values, personality characteristics and work orientation did not contribute importantly to the prediction of the selection of a career in mathematics and science. While those choosing such careers did indicate involvement as community leaders, there was some tendency for those choosing careers in other areas to be even more involved.

Parental values were also related to career selection. Among both sexes, graduates whose mothers believed strongly in the development of individual talents without linking them to sex role, and whose fathers or mothers encouraged them to study mathematics and science, tended to choose such careers.[11]

In other words, the pursuit of, and even success in, mathematics and science courses in high school is apparently not enough to ensure that minority students will select math-science careers. More is needed: excellent and dedicated teachers, high quality science curricula, a strong academic atmosphere, parental encouragement, self-confidence, and the availability of appropriate courses.

Another interesting finding was that, in high school, top grades in mathematics and science courses more closely correlated with top grades in non-mathematics and science than with any other single variable. The report specifically noted that for many ABC students, the choice of a career is made very difficult by their competencies in many academic areas. This argues against the notion that minority students fail to pursue math-science careers because they are not academically able. On the contrary, ABC students possess such high ability in all areas that science and mathematics careers must compete with other options.

The study's most significant finding, however, was that ABC students pursue mathematics and science careers at a far greater rate than do other minority students. *The proportion of ABC graduates all choosing such careers was the same as the students choosing mathematics-science careers nationally.* This finding was true for the total ABC graduate sample, and for the sample of black students considered separately. Thus, the study concludes that given a high school background that allows the choice of a variety of majors, ABC alumni are as likely to choose a mathematics or science career as are non-minority students. The intervention of the ABC experience in the lives of these students, then, has made a significant and positive difference in the selection of a math-science career.

Conclusion

Negative differences for the minority population, as compared with the majority population, are standard in indices of academic performance such as high school grades, standardized test scores, proportions of students graduating from high schools and proportions enrolling in college. But for the sizeable number of students ABC has been able to reach, a critical area of endeavor has been equalized. In a remarkably brief period of time, it has been possible for ABC's minority students to build the personal enablers for choosing careers in mathematics and science, if they care to, to the same degree as non-minority students.

A Better Chance has made this difference by providing the opportunities and experiences that students apparently need to maximize their abilities. Among the most important experiences that students apparently need are self-perceived ability, enrollment in advanced courses, an influential math-science teacher, and a positive perception of the math-science curriculum.

The Mellon Study:
Significant Predictive Factors of the Academic Achievement of the 1986 Class of Graduates of A Better Chance, Inc.

Background and Rationale

The ABC application-selection-referral process requires that each of its applicants take the SSAT. Reports of the scores obtained from it and from other standardized tests become a part of the student record maintained by ABC. However, ABC staff have long believed that traditional admissions criteria may not have the same predictive value for ABC-referred students as for others in a typical independent school applicant pool. Specifically, ABC staff involved with matching and referring ABC applicants to member schools have been concerned that ABC applicants--particularly those with low standardized test scores--may be assumed by member school admissions committees to be unprepared to take up difficult academic challenges, when in fact they are not.

In the experience of the ABC staff, ABC applicants generally do not deviate from the findings of national surveys which report that Black, Hispanic and Native American students achieve relatively low scores on standardized tests. This is a general finding and this group was no exception. However, it is also our experience that most of these students, having matriculated at ABC member schools, do well at these schools.

ABC staff developed the idea for the Mellon study specifically to provide a stronger rationale for urging admission of ABC applicants to those of its member schools where high standardized test scores traditionally have been viewed as prerequisite to academic success and, therefore, to admission.

Methodology

The sample population was 239 ABC students graduating from ABC member schools in 1986. Of this group, 51.9 percent were male and 48.1 percent were female; 65.9 percent were Black, 21.8 percent were Hispanic, 9.2 percent were Asian, and 3.1 percent had other backgrounds. Fifty-five point one (55.1) percent of the students entered ABC schools in the ninth grade, 39.1 percent entered at the tenth grade level and 5.8 percent were eleventh grade entrants.

Academically, the 1986 class of ABC-recommended students had performed quite well. Their first year mean grade point average was 2.8 (2.0 = C), with a standard deviation of 1.24. Their second year mean grade point average was 2.7, with a standard deviation of .59. Although the second year mean is slightly lower, the much-decreased standard deviation shows that nearly all students were by that time performing just under a "B" average, and that about one third were achieving a "B" average or above.

In order to carry out the objective of correlating the academic performance of the 1986 graduating students to the specific techniques of assessment employed by the ABC staff upon these students' initial application to the program, it was necessary to review carefully the entire ABC application-selection-referral process.

In assessing the potential of our applicants, we acknowledge that the results of standardized tests such as the SSAT can impart important information about skills that are linked with academic success. However, we also strongly believe that a student's potential blossoms when he/she is offered an enhanced opportunity and challenged to accept it. Thus, the ABC selection process is specifically targeted toward seeking every possible reason, among a number of possible selection factors, to assume and uncover applicant ability and potential. ABC raters therefore do not place particular emphasis on standardized test scores, particularly when these scores are low. Instead, they look for such non-quantitative factors as leadership ability, broad academic and social interests, determination, creativity, tenacity, flexibility, and desire to excel. Records from sending schools are carefully examined, as are statements from parents, writing samples, and teacher comments.

Once students and schools are matched and referrals made, the ABC staff must work particularly hard to encourage acceptance of students viewed by admissions officials as only marginally acceptable. Far too often, in ABC's view, schools report that negative admission decisions have been made based on low applicant test scores. As it has been pointed out, frustration over these recurring comments, accumulated over years of work with member schools, which prompted ABC to seek the information which led to the study of its 1986 graduates.

The key variables employed by the staff in making referrals were identified, described and quantified as follows:

1. The ABC Performance Indicator (ABC-API), an index based on students' academic performance in their sending schools
2. The ABC Comprehensive Admissions Assessment (ABC-CAA), an overall rating given by ABC staff, based on all applicant information
3. The ABC Mathematics/Science Assessment, based on information from "sending" teachers, and counselors and/or principals
4. The ABC Language Assessment; also based on information from "sending" teachers, and counselors and/or principals, as well as student writing samples
5. The Secondary School Admissions Test (SSAT) Verbal score

6. The SSAT Quantitative score
7. The SSAT Total score

Findings

While students' first year performance could be predicted, the correlations were not high. Among the predictors studied, those with the highest correlations were the ABC Performance Indicator (ABC-API) and the ABC Mathematics/Science Assessment. The lowest correlations were obtained for SSAT scores.

By the end of the students' second year in their ABC schools the ABC-API and the ABC Comprehensive Admissions Assessment (ABC-CAA) had become the first and second major predictors of their performance there, followed by the ABC Language Assessment (third), the ABC Math/Science Assessment (fourth), and the SSAT Quantitative score (fifth).

It should be noted that the ABC-CAA (Comprehensive Admissions Assessment) is performed by people who have seen the SSAT scores, and the assessment is therefore, affected by these scores. In that sense, then, the assessment provides a "correction" to these standardized test scores, because ABC raters view them in the context of other information known about the student. The ABC-CAA, then, "corrects" some of the measurement and predictive error contained in the scores.

An additional intriguing finding was that, in general, students who left their ABC schools prior to graduation did not do so for academic reasons. The grade point average of these students was in fact higher than the grade point average of the students who stayed to graduation. This might indicate that first year students who are performing well may need as much additional encouragement as those performing at a lower level, even though this support may not seem as necessary.

Conclusion

Through the years there has been a great deal of controversy over standardized testing and what that testing does in fact measure. Particular, questions have been raised regarding the fairness of these tests for non-majority students, especially since many educational opportunities are awarded or denied on the basis of scores earned. In fact, questions about the appropriateness of using standardized test results as admissions criteria--for majority as well as minority students--has caused several colleges and universities to stop requiring them.

ABC has recently released the results of the Mellon study to appropriate faculty and staff at all of its member schools. In a Research Brief, dated February, 1988, ABC has strongly recommended to member school admissions officers "that SSAT scores not lead [them] to make negative admission decisions on students referred by ABC. Our data indicate that these scores have already served their most useful function by being considered, along with other criteria, to form ABC's Comprehensive Admissions Assessment. Considering them further, then, gives them credibility which is unwarranted for ABC-referred students."

We recognize that when a predictor such as the SSAT is used for selection, the spread of scores among the selected group will be smaller than its distribution in the total pool. Even so, we believe that the very low correlation of the SSAT with ABC student performance in ABC schools warranted the above recommendation.

Implications

There is good reason to assume that the groups of students studied were quite similar, since ABC's selection process has remained relatively unchanged. What, then, are the implications of these studies for the attempts we all must make to assure increased numbers of minority mathematicians, engineers, and scientists? Since 25 percent of ABC graduates eventually select math-science careers, and this is a highly desirable proportion, it is reasonable to begin to look at what is implied by reviewing the academic characteristics of these students. And, since student selection for math-science interest programs is traditionally based on academic preparedness (including standardized test scores), it is also reasonable to focus on the role that traditional selection criteria play in the group's selection.

A review of their characteristics reveals students who, among other attributes:

- Tended to do well in non-math-science courses as well as in mathematics-science courses

- Had taken advanced courses in other areas as well as math-science

- When asked to rate their abilities gave themselves higher ratings in "drive to achieve", "critical thinking" and "leadership" than in science and mathematics

The results of the Mellon study of the ABC class of 1986 also suggests that:

- These students may not have had outstanding standardized test scores upon admission to their ABC schools

- Those test scores may not have correlated highly with their subsequent academic propensities--among which was their propensity to select careers in mathematics and science. It would seem, then, that the pool of minority students capable of and potentially interested in math-science careers is broader than that which a focus on traditional measure of selection may indicate.

This conclusion is supported by the work of Edmund W. Gordon, Professor of Psychology and Afro-American Studies at Yale University. In a recent report to the field on the status of engineering education for minority precollegiate and college students. He states:

> Since the number of academically able minority students graduating from high school each year is still relatively limited, it does not make sense that all of

> our institutions compete for that same pool without first determining whether the pool can be expanded . . . Indeed, unless the pool can be expanded over a period of years, continued growth of minority representation in engineering and the related professions will be increasingly difficult to achieve.

We at ABC believe we are contributing to the expansion of this pool. At one level, our work is similar to that of others who use traditional indicators to identify talented students. However, we go beyond that. We select students whose test scores and certain other indicators may not be uniformly outstanding, but who exhibit confidence, tenacity, and determination to succeed. We believe we can determine these qualities by, among other things, carefully examining student records, and recommendations and other comments from teachers and counselors. We also place great emphasis on students' writing samples, and the overall quality of their applications, seeking evidence of thoughtfulness and creativity, clearly expressed and interesting ideas, and a general sense of direction.

In summary, ABC does not dispute the view that standardized test scores, academic achievement and stated interest in math-science as a field of study or a career can all be valid indicators of students' math-science aptitude. Rather, we emphasize our experience that other characteristics can be equally if not more important.

Research-Based Initiatives

The results of our research and our observations and experiences over the years have not only influenced our selection process, but have also affected program development. The resulting initiatives range from relatively minor readjustments in assessment emphasis to major program efforts. Four recent such initiatives have been:

- Establishment of the Damon Walsh Award

- Dissemination of research results

- Review and proposed revision of the ABC application form

- Collaboration with MIT

1. The newly-established Damon Walsh Award will be given to a first year ABC student demonstrating courage, tenacity and perseverance. It is hoped that by focusing attention on and rewarding these attributes, we may encourage students to further display them.

2. We are disseminating the results of our research to all those with responsibility for reviewing ABC student applications through the preparation and distribution of research briefs. Additionally, the results of the Mellon study were presented by Dr. Johnson and Mr. Reed at the Annual SSATB Conference in September, 1987. Finally, member schools and colleges have been notified of Dr. Johnson's availability to lecture on the technology of student assessment as illuminated by her research on ABC alumni.

3. A review of the ABC application form has been undertaken. Changes indicated will be reflected in next year's application, and Dr. Johnson will work with the ABC staff to explore possible ways to further quantify the ABC assessment process.

4. By far the most extensive application of our research efforts has been the initiation of two enrichment programs, developed in collaboration with MIT and offered during the summers of 1985 and 1986, to encourage high school students to enter the scientific fields. Emphasis was placed on recruiting and selecting excellent students for these programs with high potential in science, but who also may not have had the opportunity or encouragement to explore a scientific career. It was ABC's hope that introducing students to the factors defined by the Ford Foundation study as significant in influencing career choice at a point when academic preferences were still being shaped would encourage interest in the medical sciences.

Implementing a New Strategy

A Better Chance will continue these efforts and, it is hoped, expand them, as we search for even more successful ways to assure minority students the opportunity to select careers they will find satisfying, and which will allow them to make the fullest contributions to society of which they are capable. The research findings and experience of A Better Chance indicate that three areas need attention:

> *First*, high school students need to be actively and consistently encouraged and enabled to take advanced mathematics and science courses.
>
> *Second*, high school students need to be actively and consistently encouraged and enabled to see themselves as able to achieve in mathematics and science. Teacher encouragement and personal interest is critical in developing perceptions in these students that they are capable learners.
>
> *Third*, the scientific aptitude of students of all ages needs to be assessed by means of criteria designed to broaden, rather than narrow, options which encourage interest in scientific careers.

The success of the ABC program indicates that steps toward these goals should be taken at the junior high school level, or even earlier, so that their full impact can be felt at the high school level. Students believing themselves able will tend to take more mathematics and science courses, and continued success in these will lead them to consider careers based on their abilities in several areas of endeavor.

The experiences of the ABC alumni implies that if students' abilities have been broadly and affirmatively developed, then a fair number of them will in fact elect to pursue science-oriented careers. All students interested and competent in science and mathematics will not choose careers in these areas, nor should they. However, they will have genuine options, and these options will be based on their strengths and not on their deficiencies or society's. And we will have taken several giant steps from where we are as a nation to all that we might become.

Notes

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10. Ibid.

11. Ibid.

Discussant Reaction:
The Minorities in Medicine Program

Maxine E. Bleich

As part of a twenty year program to increase the number of minority students academically prepared for medical school, the Josiah Macy, Jr. Foundation for the past five years has supported programs that provide an academically rigorous course of study for specially selected minority students in grades 9 to 12. The projects were not exclusively extracurricular but, rather, were fundamental to the students' course of study.

Located in economically underprivileged settings, the high schools enroll disadvantaged students and have previously been unable to provide a strong academic program. Three programs are in New York City: at the A. Philip Randolph High School, in Harlem; at the DeWitt Clinton High School, in the Bronx; and at the Clara Barton High School for Health Professions, in Brooklyn. The other programs are at 30 small rural high schools in western Alabama, including some of the nation's poorest counties; at the Hillhouse High School, in New Haven, Connecticut; and at the Tuba City High School, in Arizona on the Navajo Reservation. The grants, awarded to institutions of higher education, are used to further collaboration between colleges, public schools, and local and state public-education authorities.

What Has Been Learned?

The ninth grade is not too late to introduce a rigorous academic program. Despite poor preparation, students can overcome deficiencies in mathematics and reading and can benefit from and enjoy an enriched course of study. Many minority eighth graders are motivated and eager to achieve. Most of their parents share their desire for achievement but are ignorant of what is required for academic success.

Almost uniformly, the teachers and administrators in the Macy-sponsored programs have been working in their school systems for twenty years. They have been pessimistic about their students' ability to achieve academically and cynical regarding their school systems' efforts to identify and educate minority talent. This pessimism and cynicism, which is partly related to egalitarian ideas that preclude individual or group achievement, have been reinforced for twenty years by the poor performance of the schools and youngsters.

These attitudes are not totally unfounded. Indeed, most of the Macy-sponsored youngsters do not start out as honors students, nor are their work habits strong enough to guarantee honors-levels work. But by the junior year the vast majority of them have not only maintained honors grades but have also achieved scores above the mean on nationally normed tests such as the SAT and ACT. These achievements and attitudes have had major effects on teachers' attitudes.

To date, more than 2,100 high school youngsters have enrolled in the Macy-sponsored projects, and it is anticipated that annually more than 4,500 students will eventually participate. If the present retention rate of 70 percent continues, more than 700 minority youngsters will graduate each year with an excellent high school education. Further, if the existing levels of achievement are maintained, most of them will be honors students who score high on nationally normed tests.

It has taken two or three years for the projects to stabilize, for all parties to work together for meaningful achievements, and for the programs to be fully integrated into the schools. Teachers, administrators, and university faculty have forged productive working relationships that were long considered unattainable.

The Alabama project and two of the New York projects have completed five years. The graduating classes have been outstanding: each has included 70-80 percent of the original cohort of youngsters. Almost 100 percent of the graduates are going to selective four-year colleges, many of them with significant financial aid. More than 50 percent of the graduates intend to study medicine or a related health profession, or plan to obtain a degree in a biomedical science.

The Macy Foundation's program of documentation tracks the high school progress of the youngsters. In addition, they will be followed through their undergraduate years, to learn about their experiences and intentions to enroll in programs that prepare for careers in medicine, the related health professions, and the biomedical sciences.

Current Status of Minorities in Medicine

Despite the efforts of the past twenty years, medical school enrollments of minority students are down. Enrollment of blacks, for example, has declined from a high of 7.8 percent of the total medical student population in 1974-75 to less than 6 percent in 1983-84. Further, their rate of academic progress has slowed, and the percentage of black graduates has declined from 5.5 in 1977-78 to 4.8 in 1981-82.

Of the 2,644 blacks who applied to medical school in 1981, 984, or 37 percent, actually matriculated. In 1985 the number of applicants has fallen by more than 200, and 952 actually matriculated--representing a decline of 32 students. Despite the perception of minority applicants as academically better prepared in the 1980s than in the past, their academic progress has slowed. More than 16 percent have to repeat the first and second years, up from 14 percent in the 1970s; and the actual attrition rate has edged up to close to 11 percent from around 5 percent in the 1970s.

In 1984 Joan Baratz, Director of the Educational Policy Research and Services Division of the Educational Testing Service, surveyed minority students who took the MCAT, as well as enrolled minority medical students. She found that the number of black candidates to medical school was evenly divided between men and women, and that twice as many Hispanic males as females applied. The experience of the Macy-sponsored high school projects is quite different. In both the applicant pool and in enrollment, the students are overwhelmingly female.

Baratz also found that minority candidates for medical school were relatively middle-class, that 75 percent of them had taken an academic program in high school; that one-third had attended in which minority students constituted no more than 25 percent of the student population. These findings contrast radically with the Macy-sponsored programs, which not only enroll youngsters from economically disadvantaged backgrounds but are located in minority high schools themselves.

Keeping in mind these characteristics of the applicant pool and of matriculating minority medical students, the following is a brief review of what is known about minorities in higher education. Again using blacks as an example: they represent 12 percent of the college-age population and 8 percent of the undergraduate enrollment. Because their persistence rates in college are lower than those for whites, they represent only 6.5 percent of undergraduate degree recipients.

Minority participation in science majors, which is important for admission to medical school or to other health-related programs, is similarly limited. Of the baccalaureate degrees conferred in biology in 1981, only 5.2 percent were awarded to blacks; they received only 3.8 percent of the physical science degrees and 3.3 percent of the engineering degrees.

After reviewing the literature, Baratz reports that the areas of weakest performance for minorities are in the biological and physical sciences and in mathematics. In particular, their apparent difficulty in problem-solving suggests, at least in part, that they have had limited opportunities to participate in academically rigorous science and mathematics courses before entering college. The Macy Foundation experience has highlighted their inadequate preparation in mathematics, science, and reading/English-language skills: many junior high school students do not spend even one hour a week of class time on mathematics and science.

According to Baratz's survey, 77 percent of the black and 73 percent of the Hispanic students had decided on medicine as a career by the time they completed high school. Interestingly, however, few of them had participated in special educational activities that might promote their success. Although nearly 40 percent had volunteered for health-related activities, less than 10 percent reported that they had received tutoring in science and mathematics in high school. Less than 12 percent had received formal preparation for the SAT, which has a significant correlation with the MCAT. Only 20 percent reported receiving guidance about college applications. These data are of particular interest, since most of the students surveyed by Baratz had graduated from advantaged high school settings.

The following are brief summaries of the Macy-sponsored high school programs.

Alabama--Biomedical Sciences Preparation Program (BIOPREP)

The University of Alabama College of Community Health Sciences in Tuscaloosa, a clinical campus of the university's medical school, was established to increase the number of health professionals practicing in rural Alabama. In an effort to develop rural talent, BioPrep was designed to work in five rural high schools in three of the states's poorest counties, where more than half of the families live below the federally designated poverty level. The median school years completed is less than 8.5, and prior to BioPrep the school systems had been unable to identify "gifted and talented" youngsters using federal criteria.

During the program's first four years, more than 100 youngsters were enrolled in a rigorous academic program emphasizing science, mathematics, and language skills. Tutorials, enriched science laboratories, and independent study were offered at the schools; bimonthly Saturday sessions and six-week summer programs were held at the University of Alabama. Curriculum development was a collaborative venture between the high school teachers, BioPrep staff, and selected university faculty. Extensive in-service training was provided, and an evaluation was completed, using schools in neighboring counties as controls.

After four years, much has been accomplished. Of the originally selected 114 students, 79 percent were retained in the honors program--and all 114 went on to college. Macy graduates have received multiple acceptances from selective schools, and many have received scholarships. More than half expect to pursue careers in medicine and the related health professions. All the Macy graduates took the mathematics placement exam given to incoming University of Alabama freshmen: 88 percent of them placed into calculus or pre-calculus. By contrast, less than 10 percent of the 2,600 Alabama freshmen do as well. These are crowning achievements for schools that have traditionally sent few graduates to college.

When BioPrep was established, there were serious doubts about the schools' abilities to identify a "critical mass" of youngsters with the potential and motivation to enroll in rigorous academic studies. These doubts have proved to be unfounded. Several schools have enrolled new classes in each year of the program, and in each setting there is a growing interest in, and demand for, an even more rigorous curriculum.

Other areas of initial concern were the teachers' abilities and willingness to try new materials and teaching methods, but for the most part, the teachers have been enthusiastic participants. Indeed, their achievement have intrigued and motivated other teachers and school systems. BioPrep now includes 30 schools in western Alabama, most of them financially poor, serving primarily an economically disadvantaged black population. Each school has established and supports an honors program for approximately 20 youngsters each year. Thus, when the programs are in full swing, each will enroll 80 BioPrep students in grades 9 to 12.

The New York City Program: A. Philip Randolph High School, Manhattan; DeWitt Clinton High School, Bronx; Clara Barton High School for Health Professions, Brooklyn

The New York City projects are a joint venture with the New York City Board of Education and three colleges that constitute the City University of New York: Brooklyn, City and Lehman Colleges. Macy Foundation support provides enriched science and mathematics laboratories, research projects, tutoring, cultural enrichment, staff development, and summer programs for tenth and eleventh graders. The Board of Education supports reduced class size, additional instructional periods, additional guidance and counseling services, a school psychologist, supervisory personnel, and summer programs for entering ninth graders. The projects have also served as a model for a statewide grant program designed to prepare minority students for the licensed professions, with special emphasis on medicine and the related health professions.

With Foundation assistance, a residential summer program for rising eleventh and twelfth graders, entitled CAMPSTAR, was established last year (Commitment, Achievement, Motivation, Progress through Stress on Thinking, Analyzing and Reasoning Skills). Additional support to continue the program has been obtained from grants programs administered by the New York State Department of Education. CAMPSTAR is designed to develop and strengthen analytical reasoning skills. Laboratories in applied mathematics, biology, and chemistry are coordinated to demonstrate how selected principles and problem-solving strategies can be used across the disciplines. Vocabulary, reading, and oral expression also are emphasized.

Hillhouse High School, New Haven, Connecticut

The Hillhouse project, jointly funded with the Herzog Foundation, is part of a statewide School Improvement Program based partly on techniques developed by the Yale Child Study Center. After an initial year of planning, the ninth and tenth year programs are now in place.

Working with a specially structured Steering Committee comprising administrators, teachers, parents, children, Yale Child Study Center staff, and representatives of the Connecticut State Department of Education, the faculty of Hillhouse has determined the students' educational and social needs.

This program differs from the other Macy-sponsored programs in that the Macy students are not grouped together for their four years of high school, but, rather, are grouped by reading and mathematics levels. Thus, Macy and non-Macy youngsters take the same classes. However, the Macy students have a required curriculum and are brought together for a variety of specially designed enrichment activities. It is anticipated that the Macy youngsters will be enrolled in the same courses at the beginning of their junior year.

The school day has been extended for the Macy/Herzog students, enabling them to receive tutoring and to prepare for standardized tests. They also participate in academic enrichment activities designed to inform them about career opportunities in the health professions, as well as the academic preparation necessary to pursue such careers. Moreover, tenth grade students are assigned teacher-mentors, with whom they maintain a continuing advisory and counseling relationship throughout their high school years.

Tuba City High School, Tuba City, Arizona

After a year of planning, the ninth and tenth grade programs have now been implemented. The project was initially conceived as an advanced science and mathematics program, with emphasis on the physical sciences. However, the concept proved to be too abstract and lacked an organizing theme for the students and teachers. To give the program a focus, the theme has changed to approximate the other Macy-sponsored projects; and BioPrep, the name of the Alabama program, has been borrowed.

A program in physics and applied mathematics was designed for the ninth grade, and a special biological chemistry course has been developed for the tenth. Counseling, tutoring, and special summer programs are included, and funds have been made available for educational trips off the Navajo Reservation.

For most of the first year, only about 25 percent of the 110 project students were performing well. Part of the academic problem was due to inadequate preparation for high school, poor motivation, and limited facility with the English language. However, much to everyone's surprise--not least the students'--most of them have done well on standardized exams given at the close of the school years. Students who had tested below grade in many subjects in September scored at levels from one to four years above their grade in June.

Summary

These brief program descriptions are meant to suggest the kinds of relationships that can and must be established among public schools, colleges, and professional schools. The nation provides tax-levy dollars for the education of its children; it is essential to help the schools establish academic standards and to develop programs that enable students to meet them. The activities are labor-intensive and require atypical institutional relationships. The need is great, but the demonstrated achievements of the youngsters are even greater: they are little short of startling!

Discussant Reaction: Better Measures: Developing More Minority Mathematicians and Scientists

Belvin Williams

I thought I would divide my remarks into just a few parts. One, I'm going to do what I was asked to do by the conference organizers and respond to Judith Griffin's presentation. Two, I thought that I'd raise some other questions, one or two of which might be directed to Ms. Griffin, and others which might be directed to all of us who are interested in the more general problem of trying to increase minority talent for the sciences. So I'll start by first addressing some comments to Ms. Griffin's remarks.

I'll begin talking about the way I perceive the logic of the problem of the underrepresentation of minorities in science and math. There are two parts: 1) the logic of the selection problem, and I think ABC is in the middle of that; and the larger problem 2) the logic of increasing the minority pool.

One of the things I thought I would explain is that ABC is trying to find a set of predictors or selectors which will enable them to identify children who are likely to be successful in boarding schools and independent schools. I think that what they do is quite admirable. I've spent some time in the ABC office watching the staff go through the files, reading the cases, and having the discussions about the kids. As Ms. Griffin says there's a great deal of care and attention given that. Properly, I think, they are cautious about the use of the SSAT and since Ms. Griffin has spent a great deal of time on that instrument I thought I should comment about it. I must admit I do this with a certain amount of embarrassment for several reasons. One, since I was senior vice-president for all the testing programs at ETS, one of my small responsibilities was the SSAT. The SSAT has no relationship to the SAT, which is a test published by the College Board. I thought in preparing for this paper that I would go back and look at some of the data on the SSAT to refresh my memory. I called the program director at ETS and asked about the validity studies for the test, and where I could find the test. I consulted the *Buros Mental Measurements Yearbook*, which every good psychologist uses, and I could find no reference to the SSAT. There were no public reviews of that test in the *Ninth Mental Measurement Yearbook*. I also looked at *Tests in Print* and I could still find no reference to the SSAT. I looked through the ETS catalog of test collections, and I couldn't find the SSAT there either. So I called the program director at ETS, and I said, "Why isn't this test listed in any of these places that you're supposed to look for reviews?" and there was no answer to that.

In general, the test doesn't enjoy the wide support of validity studies that the SAT does. And I think that the ABC staff is well advised to use it with caution. I also think the Secondary Schools Admission Council should do something about finding out what the SSAT measures. It clearly has very little evidence to recommend it as a differential predictor, and certainly I think it's wise to take that into account, and whatever subjective weighting the ABC staff uses.

I would like to relate one of the problems that any of these tests have to something that was discussed about the SSAT. When the SSAT was first created, there was a question about the meaning of high and low scores. There was a fair amount of confidence about the meaning of a high score, that is, that there was mastery of certain kinds of skills that were certainly useful in taking a test in academic work. Even more, it was related to levels of success in the first year of college as measured by grades. But the meaning of a low score was not clear. A low score did not mean no aptitude, because that's not the nature of the scale. It's not like a ruler, not like a measure of weight where you say there is weight or there is no weight, because of the scaling of the instrument. So when the scores are low on the SSAT, ABC tends to disregard them, and they look very carefully at other indicators. That practice has been of major interest as we try to broaden the number of indicators that can be used to identify talent.

Let me dwell a little longer on the logic of this problem. We have three variables which contribute to the situation at ABC: 1) trying to find a predictor or predictors; 2) looking at the criteria that are going to be predictive, and I want to talk about that; and 3) the relationship between the two.

In much of our thinking about the identification of talent, a great deal of attention is paid to the selection device: an overemphasis is placed on it, I would even say. We have discussed at the Talent Identification Program advisory board meetings whether too much emphasis has not been placed on the SAT or the ACT to select and identify talent. It is quite clear that the SAT or the SSAT do not identify all of the cognitive skills that are necessary for college success. So first, you have an initial restriction of test content. Second, even if you had at least samples from all of those domains that were relevant to college success, there is always measurement error. That's just the nature of empirical inquiry. The SAT, luckily, only has a measurement error of plus or minus about 30 points. However, the measurement error for the SSAT is probably a little larger, because I'm not sure that the reliability figure is as great for the SSAT as for the SAT. Third, the criterion always has measurement error, regardless of the criterion. Now at ABC they use another indicator of academic performance, academic grades. In some cases schools recompile the index of a GPA. I suspect that's not a bad thing to do, but when you try to correlate some kind of test indicator to school performance by using first year grades or second year grades, you have to account for the elements in a grade point average that add to the error problem.

Even if you had a perfect criterion and a perfect predictor there is always the problem of the statistical function that relates the two. Typically that's created via a linear relationship like correlation or regression, and there is error in that. And the kind of variable that Ms. Griffin was talking about--persistence, tenacity, the ability not to become discouraged when the going gets tough--no one really knows whether these have a straight linear relationship to measures of success. They may have other kinds of relationships. I'm sure that in some instances there may still other variables involved, for example a "humility factor" represents gratitude of a student for the efforts made by others. How you get a fix on the effects of these variables is not clear. I'm not persuaded that all of these variables either need to be quantified or can be quantified. I do think, obviously, quantification has its advantages; at least you can state things more precisely and then go back, we hope, and try to find the location, source and size of the error. Aside from that, not everything in life has to be quantified. So, there are three parts of this relationship, the predictor, the criteria set, and the relationship between these two that is complicated.

The ABC staff spends considerable time looking at what goes on in the schools. That's atypical for the prediction situation. Typically, to get into college you take the ACT or SAT, or the GRE if you're going to graduate school. Students don't know if the situation at Duke is the same as Harvard or Columbia or the University of Kansas; there all kinds of different things at work.

But at ABC the staff are at an advantage in that they spend time with the headmasters, headmistresses, the admissions staff. They visit the college to determine if their kid will or will not fare well in that environment. It's one thing to say that Phillips Academy at Andover is a great school, but that part of Massachusetts is cold and isolated, and Exeter may be even worse. At ABC they do an excellent job of trying to match some of the dispositions of the kids with what they know about the school. That's a special charm about ABC, and it's a task that I'm not sure can even be performed well by the admissions office of the particular school. I don't think that admissions offices staffs gain a distance from their institution. Most of them come trying to find the best students for their schools. They have a job to do. ABC on the other hand, clearly has a mission to help the schools find talent, but at the same time they have to act as advocates for the kids. This particular role of acting as advocates is very important for minority kids, especially black kids and Hispanic kids in particular in the United States, because there has been a history of discrimination against minorities in most if not all of these institutions. That's just one of those facts one has to try to overcome and not pretend that it is not an historical fact. Nor can we pretend that all of the relevant variance for success in college can be picked up by the standardized tests.

I wanted to comment on the issue of increasing the minority pool in science, technology, and math. It's clear from what Ms. Griffin described that there's a residual, there's a set of kids that don't get into college. There's a set of kids that don't get in the TIP program, as far as that's concerned. There's always, as I said, measurement error. There's a set of false negatives, if I can put it that way. If we really wanted to increase the pool, it might be advisable to see if we could adopt some of the kinds of strategies--if it could be done in a cost efficient way--that ABC has been using to identify kids they place in boarding schools and independent schools around the country. It appears to me on the basis of sheer numbers that there are lots of minority kids out there. If you look at the U.S. census data, I don't think that one could argue very strongly that there aren't very many minority kids. Even if you took only one per cent of the age cohorts, from 14-17, 18-24, one per cent would be a huge number of black kids alone, to say nothing of Hispanic kids and others who are in this group, who could be identified for higher educational experiences, and with considerable success. How one broadens the pool of talent is a very difficult problem, because of the finances involved, and so on, but this is what we're here to try to discuss.

I wanted to end some of my comments with some interesting things, especially with regard to social context. Social context is very critical, and I'll just touch briefly on some experiences that we have had with the Macy high school programs. The importance of the students perceiving--as well as the teachers perceiving--that they can succeed in mathematics and science cannot be undervalued. I don't think that it can be underestimated how important it is that the student feels that the adults who are in responsible positions believe that they can succeed, and believe that they are going to get support for their efforts. Mathematics itself is not very complicated. Taking the SAT is not very complicated. Those are straightforward kinds of problems. There are a lot of other variables that tend to get in the way of these students, and there is not that kind of support structure as in the case of ABC as an organization.

In the case of the Macy programs, one of the things that we have discovered is that you had to convince the teachers and the principals that the kids could do it. You had to say, "Hey, I look at your kids, and I notice that they're getting a combined score on Verbal and Mathematics parts of the tests of 900. I have no reason to believe that they couldn't get 1200. So, why don't you work or their verbal skills, why don't you work on their math, why don't you help them understand certain things. Give them more reading assignments." And you know, we've been documenting the progress of the students year by year, and those scores go up. They do get 1200 on the SAT, in point of empirical fact.

The teachers and some of the principals turn around and say, "My God, they are able to do it," and there's a certain kind of pride in all of this. So the social context in which the child finds him/herself is very important. And I must say we have observed kids in New York, the Bronx, Brooklyn, and Manhattan, who come from very trying circumstances, who are able to achieve. That achievement is, I think, a real feather in their caps, and to all the people who have assisted them.

I want to suggest that in the interest of increasing the number of scientists and mathematicians there is also a need to increase minority psychometricians. When you think about the history of educational measurement in the United States there have not been too many minorities who have been significant in this dialogue. There should be because of the issues which surround what variables you look at and how you look at them. And it has to be done with rigor. There's nothing that should be sloppy, or soft about this. But it has to be done with rigor over a long time, and I think one way to do that is getting people who are interested in understanding some of the other factors that enable varieties of children from different ethnic groups, black, Hispanic, Native Americans, to survive and achieve. I think that unless there are minority researchers doing it, that it probably won't be done. I suspect it's no different than the situation with women in education. Unless there are women who are concerned about understanding why women achieve or do not achieve, it won't be done. So the research needs to be done by people who have a stake in the results; there's nothing wrong with having a stake in things. It's a very constructive bias.

Finally, I'll address a question having to do with the situation of the public school program where the students are living with "host families". I wonder whether there's been any thought given to the advantages of having the students live with these families, especially in places like Richfield, or Stamford, Connecticut. I have a great feeling for Massachusetts and parts of New England, as you know, but there are parts of Connecticut that always remind me of the "man in the grey flannel suit." Parts of Connecticut change very slowly. No matter how long you live there or in Massachusetts, you're never one of them because your parents didn't come over on the Mayflower. In any event, I think that it's an interesting question. Some of Ron Edmonds's research found that the families become advocates for the kids. Both Ms. Griffith and I know that some of the families have been significant in this program. Some of them I've known, IBM executives in particular, take this very seriously and they work very hard to do what is right.

MOTIVATING THE MOST CAPABLE YOUTHS IN MATHEMATICS AND SCIENCE

Kevin G. Bartkovich

Introduction

The subject that I have been assigned for this paper is unique in my experience. Professionals often discuss the best ways to educate the most capable youths in mathematics and science, frequently debating the merits of acceleration, enrichment, individualized study, pull-out programs, summer programs, and other strategies for working with academically talented students. The focus of these discussions is generally limited to the product of the system, specially, what skills and understanding the highly talented students possess when they leave the high schools for college. Concern for the motivation of the most capable young students is rare, yet such concern is immeasurably more important than an exclusive interest in the acquired knowledge of the product of our schools.

For example, a team of three high school students from the North Carolina School of Science and Mathematics submitted one of the six winning entries in the National Mathematical Modeling Contest. This team was the only high school team entered; the other teams were from top universities around the nation. What enabled this group of young students to do so well? Clearly they possess brilliance to go with an excellent mathematics education; however, talent and knowledge alone did not enable them to work for nearly four straight days with little sleep to prepare their contest solution. A crucial aspect of their effort was the motivation to pursue excellence and to use their talents to the fullest extent possible.

The emphasis on motivation in the title of this paper implies that we are interested in more than the test scores or amount of advanced standing an individual has achieved. On the one hand, the product encompasses what the student has already achieved; however, interest in the motivation of an individual looks forward to future achievements. Given a certain level of expertise, motivation is a major factor in determining what a young person will accomplish as an adult. Striving to give our brightest young people the best training possible is a worthwhile goal, yet without strong motivation even the best education can yield unsatisfactory results in the long run. Profound implications follow from placing high priority on the motivational value of the curriculum. In this paper, I suggest three key ingredients for motivating talented mathematics and science students.

Content of the Curriculum

The first element critical to motivating talented students is the nature of the content in the courses offered to these individuals. For a course to have positive motivational value, several features must be present in the instructional materials.

A. Mathematics and science instruction must be built around content that reveals the dynamic nature of mathematics and science. Instruction must involve more than memorizing facts, formulas, and problem-solving algorithms. In science class, we can easily picture students tinkering and performing experiments; however, similar instruction in mathematics is difficult to imagine. For example, the law of cooling is a standard application of exponential functions found in precalculus mathematics textbooks. The textbook presentation of the law of cooling usually involves a statement of an exponential equation with several unknown parameters, as follows:

> When a cup of hot tea is left in a room to cool, the temperature of the tea is an exponential function of time. As a matter of fact, the temperature T of the tea is given by T = a x eEbt + c, where t represents the number of minutes from the first temperature measurement. The difference between the initial temperature and the temperature of the environment is represented by a, and b and c can be determined. You are given that the tea is originally 120 degree F and the temperature of the room is 70 degrees F. Also, at t = 15 the temperature of the tea is 98 degrees F. At what time will the tea by 77 degrees F?

This problem statement involves five parameters: T, a, b, t, and c. The problem is easily solved by using the values given for T at times t=0 and t=15 to find the values of b and c. The values of the parameters can then be used to find t for T=77. To solve this problem, a student merely uses simple algebraic manipulations, and the student is not required to possess any understanding of the meaning of the numbers or parameters. This presentation never brings the cooling law to life or allows the students to experience the phenomenon. In contrast, a more dynamic approach involves the following problem statement:

> Heat a cup of water to about 125 degrees F. Place the cup in a room and measure the temperature at regular intervals. Record and graph your data. Does the water cool at the same rate throughout the cooling process? Find a function that approximates the cooling phenomenon you have observed. Use your function to predict when the temperature will be 100 degrees F and when it will be within one degree of room temperature. How do your predictions compare with the observed data?

The second presentation of the cooling problem brings the phenomenon to life and enables the student to learn by discovery, in contrast to being given a formula that is an accomplished fact. The analysis of the cooling data is enhanced significantly by the use of computer software that transforms and graphs data. As this problem suggests, the availability of calculators and computers in schools provides teachers with unique opportunities to breathe new life into mathematics and science courses. Computer technology in the classroom has the potential to allow mathematics instruction to occur through experiments and discovery learning.

B. Instructional materials must be intellectually challenging to bright students. Academically talented students should be given open-ended questions and problems presented in unfamiliar contexts. A sure test of the quality of the intellectual challenge offered by instructional materials is whether sustained problems are a regular feature of a course. A sustained problem is one that requires a bright student to give a serious and lengthy effort to reach a solution. The effort may require as little as 15 minutes or as much as many hours spread over several days, but certainly more than the common situation in which a bright student finishes a homework assignment before leaving the class in which it was assigned.

Polya describes a number of ingredients of problem-solving processes in terms of insightful questions that a student must ask. Among these questions are the following:

> What is the unknown? What are the data? What is the condition? . . . Have you seen if before? . . . Do you know a related problem? Could you restate the problem? Could you restate it still differently? . . . If you cannot solve the proposed problem try to solve first some related problem. Could you imagine a more accessible related problem? A more general problem? A more special problem? An analogous problem? Could you solve a part of the problem? Keep only a part of the condition, drop the other part; how far is the unknown then determined, how can it vary? . . . Carrying out your plan of the solution, check each step. Can you see clearly that the step is correct? Can you prove that it is correct? . . . Can you check the result? Can you check the argument? Can you derive the result differently? Can you see it at a glance? Can you use the result, or the method, for some other problem?

Problems that are challenging and require a sustained effort will lead talented students to ask many of Polya's questions in one form or another. Students are shortchanged if instructional materials are not sufficiently challenging to give them problem-solving experiences at the depth that Polya suggests.

C. Instructional materials must synthesize and integrate topics from a wide range of knowledge. Talented students should see relationships between topics from many parts of a course, and not just the connection between today's topic and what was covered yesterday.

D. Instructional materials should reveal to students the importance of the specific content of a course. In other words, the frequently asked question, "What is this used for?" should receive appropriate attention. This question generally has two classes of answers--how a topic relates to the discipline in which the course is taught, and applications of a topic to other disciplines. As an example, matrices are a fixture of high school precalculus courses. Matrices have many important mathematical properties upon which more advanced mathematical concepts are based. In addition, matrix models are widely used in the sciences, such as the Leslie model of growth in population biology. Talented students should see both aspects of the usefulness of matrices in precalculus mathematics courses. Most textbooks, however, present matrices only in the context of solving systems of linear equations--a skill that most students perform quite well without using matrices.

Unfortunately, the standard materials developed for typical students do not have the ingredients necessary to be dynamic and interesting for talented youths. In fact, many textbooks are not interesting even for average students. Dynamic content, intellectual challenge, integration of topics throughout a course, and applications from within a discipline and to other disciplines are appropriate standards for instructional materials for all students regardless of ability. A lack of these characteristics in the materials for average students is cause enough for alarm; however, the shortcomings of curricular materials are even more glaring when these materials are used with the most capable students. Even the best textbooks are written for a broad population so that a large audience is available for textbook publishers. These materials are not appropriate for the brightest students since they do not require the talented students to fully use their intellectual capabilities. Rarely do the problems posed in widely used textbooks require a bright individual to struggle for a solution or to reflect upon the knowledge inherent in the solution of a problem. Concepts often are not interrelated throughout a textbook or with concepts from other disciplines. Typically what is covered in one chapter is not linked with earlier chapters, nor is it used again in later chapters. Motivation for learning a particular topic is not provided from within a discipline, and applications from other disciplines are rarely mentioned.

The weaknesses of the mathematics and science curricula for all students has received much attention in recent years, particularly in comparative international studies. Efforts are underway to address the weaknesses mentioned above; furthermore, there is growing awareness that school instruction in mathematics and science has not kept pace with revolutionary change in technology. For example, traditional high school mathematics involves many symbolic manipulations and numerical calculations easily performed by computers and hand-held calculators. In addition, high school mathematics is being examined not just as preparation for calculus, but as preparation and motivation for a wide range of college mathematics. However, even if materials are developed that incorporate recent developments in mathematics and science, that are intellectually challenging for most students, that integrate concepts over the long-term, and contain numerous applications, these materials will still require adaptation before they are appropriate for use with the most talented students.

The nature of the adaptation of instructional materials for use with talented students can take one of several forms. Suppose a mathematics program is to be designed for a brilliant eighth grade student who is prepared to begin Algebra I. Among the many possible programs, three options are:

1. Get to calculus as quickly as possible, covering only the precalculus topics directly used in calculus;

2. Progress through the precalculus courses at the typical rate of one course each year, while doing "enrichment math" such as context problems in addition to the regular course work;

3. Use instructional materials rich in challenging and open-ended problems, applications, and investigations, and thus prepare the student for a wide range of college mathematics courses, including calculus.

The first scenario has the appearance of covering the most material in the shortest time, but perhaps at the cost of giving students a static view of mathematics as a set of facts, formulas, and algorithms to be memorized. The second scenario has the advantage of maintaining the status quo, but at the risk of turning off an individual with the relatively slow pace. The third scenario is certainly the most difficult to implement, yet it is also the richest in terms of what a student will gain.

The choice of instruction content from many alternatives for the brightest students depends largely on priorities. What is really important for young students? Is it knowledge alone or knowing how to learn and a love of learning? Talented students clearly can master the same material offered to average students at a much faster pace, yet is accelerating bright students through the standard curriculum all that we want to accomplish? If so, then the goals of providing integration, diverse applications, intellectual challenge through problem solving and dynamic material will go largely unmet with talented youths. They may accumulate much knowledge at a rapid pace, yet they will fail to appreciate the dynamic nature of knowledge, nor will they be challenged to develop fully their intellectual capabilities.

Teaching for tests such as the Scholastic Aptitude Testing or an Advanced Placement (AP) examination can be a major culprit in a lack of motivational qualities in instruction. Teaching an AP course can be a positive motivator if the teacher uses the AP syllabus as a guide for developing course content. On the other hand, the test can become the exclusive focus of the teacher and the students, causing a course to deteriorate into memorization of acts solely for the sake of taking an exam. I often hear teachers complain about talented students who are "over-advanced" because they are great test-takers. The implication of the complaints is that these students are able to advance beyond their level of understanding and mastery by virtue of being excellent on standardized tests. I suggest that the problem is not a lack of knowledge, but of motivation. By focusing exclusively on tests and memorization of the required facts, talented students are able to advance beyond their level of motivation. As a result, when they do encounter difficult material, they may not have the motivation necessary to strive to overcome their particular hurdles.

No matter what subject matter is covered with talented youth, the teacher is critically important. In addition to the characteristics common to all good teaching, several aspects of teaching bright students are of special importance. The teacher must have not only an excellent grasp of the course material being taught, but also firm knowledge of more advanced content. The advanced knowledge is necessary for a teacher to be able to cope with the complex questions often posed by talented students. No matter how well-trained or knowledgeable, a teacher must be willing to admit lack of knowledge whenever appropriate. Coupled with the willingness to admit ignorance, however, must be the desire to learn and indeed to be a role model in learning new material. Above all, a teacher of talented students must be flexible, thus creating an atmosphere for open-ended investigations and discussions.

Flexibility of the Curriculum

In addition to dynamic, interesting content, the second essential element in motivating talented students in mathematics and science is the freedom to cover material at a rate consistent with an individuals capabilities. This includes the freedom to move through courses at an accelerated pace, as well as the freedom to investigate a particular concept or phenomenon in greater depth than usual.

Accelerated coverage of material must be balanced with enrichment of content. Bright students should be challenged with more than just moving at a fast pace through courses designed for average students. They require expanded and deeper instructional content if they are to be challenged to utilize fully their intellectual capabilities.

Acceleration through content areas may eventually lead an individual to advance beyond agemates in grade standing. Grade-skipping is a concern to many parents and educators because of potential social adjustment problems. Remaining with age peers often receives undue emphasis even through research does not reveal adjustment problems due to acceleration. Furthermore, for many young students, no perfect solution exists in attempts to strike a balance between intellectual challenges and social adjustment. For each individual, decisions about grade-skipping should weigh the cost of boredom and lack of stimulation with the potential for social adjustment problems.

A problem that may result form acceleration through a school curriculum is a lack of advanced courses at the upper end of the grade range in a school. For example, middle schools rarely offer any mathematics more advanced than Algebra I in seventh grade will be in a bind in eighth-grade mathematics. In high school, a student who finishes a year of basic physics may be fortunate enough to be offered AP Physics, although such schools are rare nationwide. The likely scenario for a student interested and talented in physics is that an AP course is probably not available, and certainly anything beyond the AP level (introductory undergraduate physics) is exceedingly rare except in special schools for the gifted. The lack of advanced course offerings at many schools stems from the small pool of students who would potentially take these courses. This will continue to be a problem for isolated brilliant students, especially in schools with the least resources such as in many rural and urban areas. Even the option of independent study for isolated students may be problematic because of the amount of teacher preparation required for independent work.

Limits on courses in the upper grades of a school may hold students back from accelerating through material because of the eventual vacuum they will encounter. A frequently proposed solution to the problem is to enrich the courses taken by bright students and thus allow them to be challenged without accelerating through courses. This approach sounds great in theory, but in practice several problems crop up. First, enrichment places a tremendous burden on the teacher. If an entire class is taught with greater depth and breadth than usual, then an excellent teacher will do quite well. A class with only a subset of brilliant students, however, is much more demanding since the teacher is effectively required to teach two courses at the same time in one classroom.

Even in the best circumstances, enrichment strains the background of a teacher. For enrichment to be effective, teachers must receive support for their own learning; otherwise, they will not be able to provide dynamic and currently relevant content for the most capable students. The strain on the knowledge of elementary school teachers is especially acute due to the sparse pre-service training they receive in science and mathematics. The preparation of secondary school teachers may be better, although the number of science teachers teaching outside their specialty is astounding.

Just as acceleration is most appropriate if courses are enriched, so enrichment cannot be implemented without regard for acceleration. Courses that include genuinely enriching content, and not just intellectual exercises designed to keep students in place in a lock-step educational system, necessarily involve acceleration in the sense that students are covering material earlier than they normally would. For example, a teacher might enrich an Algebra I course by drawing from topics in Algebra Ii. On the other hand, if Algebra I is enriched by introducing topics from outside the standard sequence of high school math courses, then the teacher will need to do the extra work of learning the new topics--not an easy task for many teachers considering their usual work load. The problem of teacher preparation in enrichment courses is identical to the problem of teacher preparation associated with an accelerated curriculum.

Interaction with Intellectual Peers

The third essential element in motivating talented students is providing opportunities for them to interact with their intellectual peers. Contact with intellectual peers is crucial in meeting intellectual and social needs. the academic challenge provided by other bright youths is a strong motivator for talented students. A bright student in a class with similarly talented students will have the opportunity to learn more and to learn faster, and in more depth due to the high quality of the class discussions. In addition, a class with intellectual peers often provides brilliant students with their first experience of not being the very best, which can motivate them to achieve greater excellence.

The significance of the social interaction of bright youth is at least as great as the significance of academic challenges. Talented individuals can go to school for a long time without meeting students who have the similar interests. For these young people, forming friendships with others who have similar interests is like a breath of fresh air. For perhaps the first time in their lives, they find that they do not need to hide their talent or their interests. The support and challenge that these students offer each other can often make the difference in motivating an individual to take risks in an academic career and beyond.

Highly capable students can meet intellectual peers through special system-wide or region-wide programs that pull them out of school, through summer programs, through math and science teams, through math and science competitions, and through special schools such as magnet schools or state-wide schools for the academically gifted. In my experience with such programs, students of like interests and talent are drawn to each other at every level of selectivity. For example, on a school math team, participants interact with other students who enjoy mathematics and are the best mathematics students in the school. At a higher level, members of the North Carolina state team that competes in the American Regions Math League contest in June of each year develop friendships with the best high school mathematics students in the state. At the highest level, individuals who are invited to the U.S. Math Olympiad Team training session for four weeks in the summer meet the most gifted young mathematics students in the nation. At each of these levels, I have observed the development of networks of close friendships among the participants. At residential programs such as the TIP Summer Program and the North Carolina School of Science and Mathematics, the ties that develop between students are so strong that the growth of the young people outside of the classroom may be more important than the growth that occurs within the classroom.

Recommendation

Motivating the most capable young people in mathematics and science requires implementation of strategies that involve intellectually challenging content, that provide freedom for acceleration and enrichment, and that foster interaction among intellectual peers. Lack of appropriate materials is a serious hindrance to providing challenging content; therefore, the teacher is crucial to success in any classroom. Their job is already quite demanding without trying to offer special encouragement and opportunities to the brightest students; furthermore, the informal, investigative atmosphere that is ideal for talented students is often threatening to teachers. Many teachers already do an excellent job with the best students; however, may others need support and assistance in providing for the academically talented. The best teachers are easily identified by examining the Presidential Award winners, participants in the Woodrow Wilson Institutes on high school mathematics, and the sponsors of excellent math teams in competitions such as the North Carolina Math League, the American Regions Math League, and the Mathcounts competitions.

The development of a network of excellent teachers of the academically talented can be fostered through state-wide conferences and professional teacher associations. We presently have an abundance of consultants and coordinators concerned with programs for the gifted and talented students; however, most of these GT specialists are not experts in mathematics and science. Their expertise is more broad-based and administrative, which may be fine for the primary grades; however, in secondary schools, major input is required from the content experts in the classrooms. The best teachers need to be brought into partnership with the GT specialists so that excellent classroom instruction can be combined with appropriate administrative structures.

The implications of a balance between acceleration and enrichment require flexibility and the freedom to design the best program for each individual who is talented in mathematics and science. For isolated students, independent study is often proposed as a means of providing appropriately challenging instruction. whenever possible, however, these students deserve the benefits of being in classes with other individuals of similar capabilities. when the resources of a particular school are exhausted, options outside the school should be investigated, such as college courses and mentorships at businesses and research laboratories. Individuals who are given these options will also then have the chance to meet other young people of similar interests. Classes for talented students, special schools, summer programs, and math and science competitions allow friendships to be formed that provide strong motivation for the most capable young people. For brilliant youths to participate in these special programs, however, requires that teachers and principals be willing sometimes to give up their best students to another program for the overall good of the individual student.

If the above recommendations are implemented, what difference will this make in the long run? Working from within the educational system is often frustrating. The problems that need to be addressed relative to the most capable students are part of larger problems with the entire range of students. Programs that have been developed outside of the public education system may be great for bright students, but what happens to students during the rest of the year when they are not at a three-week summer program? These are complicated issues, yet significant progress can be made by bringing together the best of both worlds--the best teachers in the schools and the best programs from outside the public schools. If the specialists on gifted and talented education could then support teachers by providing the time and resources for teachers to be learners, then we will find our schools doing what is appropriate for the most capable youths in mathematics and science.

We need to empower teachers to be able to teach mathematics and science as dynamic, challenging subjects. New curriculum materials alone will not succeed in improving teaching--such a strategy would repeat the mistakes of the curriculum reform movements of the 1960s. We must enable teachers to create excitement and discovery in the classroom. This need is the same for all teachers, yet where will it begin? Starting with the best teachers of the brightest students is one strategy. If these teachers then work with other teachers and students, then they can stimulate improvement in the education of all children.

Returning to the title of this paper, motivating the most capable youths in mathematics and science is frequently neglected because of undue concern over what is learned. The actual content of the curriculum must keep doors open to future opportunities; however, much room for diversity exists beyond the core of knowledge that should be imparted to the brightest students. These individuals require challenging and interesting material, flexibility in designing academic programs, and frequent interaction with intellectual peers. Challenge, flexibility, and peer interaction are essential characteristics of a productive environment for professional scholars. Is that not the atmosphere that we should offer our bright students? In any strategy for nurturing talented young people, the most important aim should be to produce life-long, independent scholars. In a nutshell, encouraging and motivating young students to become scholars is the business toward which we should concentrate our efforts.

Discussant Reaction: Motivating the Most Capable Youths in Mathematics and Science

Burton Stuart

Before I start I'd like to just give you a little bit of background information about myself so you'll know my perspective. I'm presently teaching at Chapel Hill High School. My background includes teaching in Denver, Colorado, in Charlotte, North Carolina, at Elon College, and now at Chapel Hill High in North Carolina for the past 15 years. I've taught in junior high, senior high, and college, so I feel like I know where students have been and where they're going. This, to me, is a good balance.

I enjoy teaching junior high kids. I feel as if I'm really needed. You can make an impact on those kids--if you can stand them. In the college area, I enjoyed the subject matter considerably, but really, you don't have much impact on the students, I don't believe.

I enjoy teaching. I teach all levels from geometry for repeaters, who have failed at one time, on up to Advanced Placement calculus. What really excites me is working with the Math Club. I started out eight years ago with seven students who would sometimes show up, and now we have about seventy people that call themselves Math Club members. A typical meeting numbers thirty to forty. We have won some national and state awards in math competition, but that's not what I enjoy the most. I get excited by going to a math contest and seeing the kids arguing answers and talking together. In the Math Club it's more a social occasion than it is learning. They do a lot of learning there; but we have refreshments, and they just enjoy associating with each other. It's something that I'm very excited about.

I'd like to make one little comment before I go to my prepared comment and that is, some of the examples that Dr. Bartkovitch was showing are from some very excellent work. I noticed them from a workshop that I did last summer. The School of Science and Math (NCSSM) people did this with the help of the Carnegie Foundation grant. They have prepared some excellent materials in what I call applied mathematics. We've already incorporated some of them into our own courses at Chapel Hill High, and we're talking about coming up with an applied mathematics course in place of calculus, or in addition to calculus, that will give students more choice.

I do want to give one word of caution to the NCSSM and the others of you who are leaders here. Sometimes I get the feeling that I came in on the opposite side of the room. When I first started teaching the big thing was theory. To prove everything from very simple mathematics on up. I get the feeling now--incidentally, I didn't like that when it came, and I have a lot of it in my teaching now--I feel like we've gone the opposite direction, and applied mathematics is the end word. I'm not ready to go whole hog that way, but I will say there are a lot of things I like about it. What I'm trying to do is stay in the middle, and take the best of both worlds.

Let me agree and emphasize that the teacher is indeed the most important factor in educating brilliant students. All of us can reach back in our background and remember that inspiring teacher who made us think and made us want to know more about the course. Dr. Bartkovitch has well indicated the preparation and communication abilities that students of such caliber should have. The sad fact, however, is that there are far too few such teachers in schools today, and indications are that, unless drastic changes are made, there will be even fewer in years to come.

There are many obstacles to encouraging talented people toward teaching. Look at the conditions such a person must face. The first, of course, is salary. One of my closet personal friends, a beginning teacher a couple of years ago, left teaching. He had a lot of potential. But he got married, had a child, and his wife wanted to stay home, but he couldn't afford that. After two years he was not yet making $20,000, so he left.

In a typical public school, a secondary teacher teaches five or six classes a day, with nearly 150 students. Sandwiched between meeting these classes is lunch duty, hall duty, bus duty, paper grading, and administrative duties. There is hardly any time to think, much less prepare an exciting class. The teacher is powerless to do anything about these conditions. Decisions are handed down from administrators, with little or no input. More often than not these decisions indicate very little understanding of the needs of teachers of gifted students.

I almost didn't last through my first year. I was teaching an eighth grade class in Denver, Colorado. One of my assignments was a study hall. The study hall consisted of one hundred eighth graders in the lunchroom supervised by two teachers. Unfortunately, the teacher that was with me was absent. Then, they almost drove me out; it was a horrible experience. But that would not have happened if teachers had been in control. The students knew better than to behave like that. I've been asked if I recommend that my best students go into teaching, and I answer regretfully that I do not, even though I have reached a position myself in which I am happy teaching. I believe such positions are not the norm. I have witnessed far too many promising teachers leave because of salary and unbearable conditions.

I would like to say a few words about acceleration versus enrichment. Acceleration is like so many things. It has worked well and it has been disastrous. In Chapel Hill our accelerated program in math for most gifted students begins with Pre-Algebra in the seventh grade and ends with AP calculus in the twelfth grade. But we are seeing more and more students accelerated beyond that, finishing AP calculus as juniors or below.

This works well for some students as they take the next course at the university and do quite well, often going on to math or science careers. In fact, the students who have gone to TIP have, without exception, done very well in their accelerated programs. However, in my opinion, the worst thing that can happen to a student in math is to be overplaced. This is a very personal thing for me because when I first went to college I was considered a good student, and they had me skip two courses of mathematics. And as I say to my students, you're not going to believe this, but I almost didn't like math. I did recover, but some people do not. I find that this is happening more and more, particularly with the students taking the AP calculus as juniors. Several of them in the last few years have struggled and then have not taken any math as seniors, and as little as possible in college.

I would like to give you two scenarios right here. One is Danny Cory, who has already been mentioned. I think he is a good example that acceleration is appropriate for many kids. In my experience with TIP, I have found that there are many administrative units that will not give students credit for the courses they complete at TIP. Students go back to school and go through the same thing over again. I find that appalling. Well, our system, at least, has made it possible for a person like Danny Cory to move up and advance as far as he can. That's a success story. On the other hand, I can think of another student who took Honors Pre-Calculus as a sophomore. He struggled and did end up improving and making a B. But it was very hard and it wasn't really pleasant for him because he had been used to making A's without any work whatsoever. Well, the student's not taking any math at all right now as a senior, and that upsets me. He should have been one year behind and doing extremely well.

I'm not sure how many students have struggled in math courses before I see them. Our success ratio with these students is high, but I'm troubled that there are many students with high ability that are turned off from math. I believe that the trouble begins with identifying students to accelerate possibly as early as the sixth grade. Often students who are well behaved and do well in arithmetic are identified as being mathematically gifted, which is often not the case. I see identifying truly gifted students as a major problem.

A third problem I see is elementary education. Again, I am speaking in the area of mathematics since my observations have been in this area. More and more has been written about the importance of early education. Incidentally, I had my own laboratory for early education with my own children. I had all sorts of theories that I wanted to try out. Many of them worked. But one thing was that at a very early age, before they could even walk, I read to them, and they are avid readers today, and I'm sure early exposure had a great impact. Another thing, developing leadership qualities: I was interested in developing these qualities in them at a very early age, so one thing that I came up with was during walks across the street. There was a beautiful place where we could walk back in the woods and all over places. So what I would do--there were two of them--is have us all take turns leading. One day my daughter would lead, one day my son would lead, and one day I would. And they were always involved in decisions. When we went out to eat, one day one child would choose where we ate. All four of us would have a choice at different days. They were part of whatever happened to the family. They are now in college, so I can give you a partial report. Indeed it worked. They are very independent thinkers and they do not do things just because everybody else does them, which I think is important in this drug-infested society. This is not a problem that we've had. On the other hand, if I had it to do over again, I think I would teach patience somewhere along the line--my son in particular. I taught him how to play bridge, and then he went and read everything he could read about bridge, and now he's teaching me. Guess what happens when I make a mistake: there is no pity shown to his father.

In this country, the vast majority of elementary teachers are deficient in mathematics and science ability and training. I have witnessed this problem first hand by teaching a mathematics course for elementary teachers several years ago, and I was shocked by the low ability and interest level I observed there. I can imagine the impact these teachers are having on their students at this very minute. For the gifted students the first seven years of school in mathematics, kindergarten through sixth grade, are wasted. The material could be learned by these students in far less time. No wonder students in America are learning algebra when students of the same age in other countries are learning calculus. To tell the truth, this is the problem that depresses me the most. Because I see it as very difficult, if not impossible, to break the chain of a poor mathematics student becoming a poor mathematics teacher, leading to more poor elementary students.

Finally, I would like to emphasize the importance of the home. It is well documented how Japanese mothers are intimately involved in the education of their children. I was also interested in reading the profiles of this year's Westinghouse Science Talent winners, all of whom indicated they were encouraged and supported by their parents. The support indicated by these students is not just an occasional pat on the back, but the total involvement of the parents in teaching and learning. You don't see this level of involvement very often in American families. I hope that with the reports, the movements going on now, and meetings such as this one, that there will be a movement to improve the conditions I've talked about. But right now, all is not well in the education community.

Discussant Reaction: Motivating the Most Capable Youth In Mathematics and Science

Solomon A. Garfunkel

I've never been a respondent before, and this is sort of fun. What I do for a living is worry about how to teach, how to show people that mathematics is interesting, that it is fun. I do that for all levels of students and teachers, and I wrote in my little notepad--I don't prepare things--I wrote, "fun, real, teachers, too." But what is so much fun is that the example that Dr. Bartkovitch raised about Newton's law of cooking is one of my absolutely favorite examples. But, I don't do it the same way. I say, "Okay, the coroner walks into a room, and finds the body at 92 degrees, so how long has the body been dead?" Let's assume the room temperature didn't change at the time. It's the same exact problem, of course, as Newton's law of cooling. But what happens is this: First of all you get the kids to find out ho coroner's really work. the coroners have a chart. But Newton's law of cooling is the exponential function and the problem is the constant. And what's exciting here is that the constant has nothing to do with the body weight; it depends on the surface area. What coroners actually do is measure height, weight, girth and they've got a little table that tells them the surface area, and then they plug that into Newton's law of cooling and they get an answer that allows them to say the body has been dead for about two to three hours. The question is, "What is the surface area?" And the kids start to figure out the surface area. That is a very hard, an incredibly difficult, problem, and extremely real.

I've got an old English textbook which has several methods. One method is the painting method. You paint the body and you try to measure how much paint is used. There's also the skinning method. And this English text from 1850 says, "This method is not recommend because the skin shrinks when it leaves the body."

The point is you can actually play with the problem. There's lots of physics and other things you could write into it. Let the kids do it and they can get closer or further away from the solution. It's presumably a legitimate problem; and they've seen enough television to know that its a moderately real problem. And they can really work on problems like that. I think that's the point. It's real, it's fun, it's exciting, and totally open-ended, because you can get better and better methods for doing it. It's intellectually challenging and also synthesizes information from all sorts of fields. You have to bring in a little physics, there's some biology, there's all sorts of things that you can look at. Questions about what it's used for don't come up at all. They know right away what it's used for.

If you can look for these kinds of applications, you can find them. In fact, it's silly to call them applications; it's just mathematics. They are just coming in one form or another. Dr. Bartkovitch used a growth example. The growth example I use is one on legislative turnover, bureaucrats and bureaucracies. It turns out if you look at survival rates for bureaucracies in governments and all bureaucrats, they are essentially exponential survival rates, totally independent of whatever the rules are that set them up. So, for example, while it was part of the United States Constitution that Congressmen would serve two-year terms, and Senators would serve six-year terms, if you look at how long an individual senator or congressman stays in office, its exactly the same. The same is true for the

Soviet Union, the Indian Parliament, the U.S. Congress, and the Senate. It doesn't make any difference.

The truth is, I think that what motivates people--students and teachers, and I'm not sure I even want to make the distinction here--is that these problems are intrinsically interesting. Dr. Bartkovitch took me to NCSSM to teach a class which I greatly appreciated. It was lovely to see all the fire behind the eyes. I was talking about sex, drugs and rock-n-roll, that's what kids talk about--and most adults I know, too. I did the randomized response technique with them, which is an example of how do you find out how many people in the population have a certain trait that they are likely to lie about. How many people are gay, how many people take heroin, how many people have taken the AIDS test? Whatever it is, we actually have to ask someone a question knowing that they will lie in response. How do you get good information about that? Read the paper, it says 16.2% of the people in this inner-city neighborhood are heroin addicts. Do you think they all responded "yes"? It's basically a probablistic model. I throw out a deck of cards, and you pick a card out of the deck. If its black you say, you answer the question. And if it's a diamond you say automatically yes, and if it's a heart you say automatically no. As long as I know what percentage of the deck is diamonds, hearts, and black cards I can figure out what percentage of the class, within certain fudge factor, have to answer 'yes' to the right question. It's an elementary probability model using a little conditional probability.

The mathematics that was invented to do this is several hundred years old, more or less. The method was used in 1976 for the first time. Up until then they'd take the numbers and they'd fudge them. Or they'd have some funny, finaglish concept that they multiply two by to get the right answer. They are relatively new problems. That's the kind of thing I'd like to see talented kids be able to do. I think if you can do that on a consistent basis--and the problems are there, and the mathematics are being used that way--I think you can excite and motivate people, and get teachers interested. It's a lot more fun to teach this way, than to teach other ways. The problems are open-ended and you can keep following down the road.

Dr. Bartkovitch talked about the MCM, The Mathematical Modeling Contest that we, COMAC, actually administers. I'll tell you why those kids who won that contest won--because they took the extra step. The problem, by the way, was a drug-running problem. People are people, you know what they are interested in. The problem is stated that there are two sides, with the side in the helicopter trying to overtake the boat. The boat is located directionally; the helicopter takes off to intercept the boat. The helicopter travels three times the speed of the boat, but when the helicopter is within 500 feet, the boat hears it, and can now take evasive action. Question: what is the optimal search pattern for the helicopter? How long would it take to find the boat within a 95% confidence interval-because it's clearly a probablistic and statistical problem. The Coast Guard Academy submitted a paper on the problem. They've got practical experience on the street in this, they do if for a living. At any rate, the point was that people apply these methods, which are very sophisticated, by the way, involving a lot of very heavy mathematics. But the kids took it the extra step. A lot of people came up with a similar answer, but the kids actually considered what would happen if the weight of the boat was so at a certain level, what if the driver did something, and so on. They actually looked at the model one step further and, interestingly enough, most of the college teams stopped. They got a pattern, probability, and numbers, so they stopped. These high school kids just kept going. We asked them to look at the model, at how to expand it, from the captain of the boat getting drunk to the waves being too high a wave coming in or a heavy wing; they just kept looking at different problems that could have cropped up with the model and different ways of looking at it. If that isn't the best possible thing to have happen I don't know what is, and I'm sure that's why the paper was chosen.

When we talk about materials like that, of course, the point is that texts don't do the job. Textbooks are reactive and they take time to change. That, of course, is why we are in this business, because we produce modular materials at high school and college levels for teachers and students, of the kinds of examples we just talked about--to give people the option. One of the things you can do with the modular approach, and I'm not trying to sell anything here, take the 10 or 20 pages necessary to explain the application field that's not the mathematical field. No textbook will ever do that, which is the real problem. No textbook is going to expend time teaching the biology, chemistry, or social science of a problem, because then the books would get bigger and bigger. That's why we produce various modular materials. First of all they are flexible, pick and choose; and second of all because you can actually put in one place all the kinds of outside material you need while you learn the mathematics.

The modular concept makes the world a little more flexible and allows for something else Dr. Bartkovitch was talking about. Yes, students should move at their own pace, accelerate depth versus speed. Freedom of pacing, interaction, it's so obviously right, it's hard not to talk about. We could have done an individual contest, with kids sitting in a room like the Putnam does, for six hours behind a locked door--that's the Putnam approach. But we said basically, that's not the way people do problems in the world, in any mathematics, nobody works that way. That's the reason I think we decided to do the modeling competition the way we did: We decided students would work as teams with resources. The only thing we did to make it a true competition in the MCM is that we don't allow them to use people. They can use any and all inanimate resources: they can use libraries, computer programs, anything they want, as long as they don't go to some other professional and say, "How do you do this?" That's the only thing that's disallowed in the program. In fact, people have different skills, so that kind of interaction is the absolute best. It's the way people should learn; it's the way they are asked to act in the real world.

I should also point out that the "teachers, too" part. You're right in making the point about teachers having a terrible life: it's true. On the other hand, presumably, many of the teachers into the field because they care about and like mathematics and, at some point, they found someone responding. Everytime I've ever talked to groups in high school--elementary school teachers for that matter--the same kinds of examples are fun, and students and teachers remember and enjoy them. We've got to treat the teachers the same way we would treat the bright students--or all students, for that matter. Like them, respect them, and play a little bit. It would be nice if we could all effect the salary scale and the work load and all of that, but given that we don't have that power at least we can give them some serious enjoyment. That's basically the only approach.

The last thing I would say is that I think the issue of applied versus pure mathematics is over. It's all one subject. Even at the research level now, nobody can tell the difference anymore. People are still fighting it because there's some good old jokes you want to be able to tell, about how you can tell a pure mathematician from an applied mathematician. The mix is so thorough, it no longer makes sense to separate the two. It was fun, and it was useful, but it isn't true any more; it's not a real debate anymore. And all of these things I think fit in different fields. We can look at the subject of mathematics in a lot of different ways.

THE DEVELOPMENT OF EDUCATIONAL SUPPORT SYSTEMS FOR THE ACADEMICALLY TALENTED: THE TALENT SEARCH CONCEPT

William G. Durden

Within the last five years, one national report after another has examined the state of American education and, all too often, the results have been less than positive. Low teacher salaries, lack of coherent curricula, inadequate student performance, high student and teacher dropout rates and irregular local, state, and federal funding have made the American response to educating its children and youth a very uncertain affair. Among the remedies often proposed is a closer working relationship between schools and colleges. This proposal is advanced in a larger context, a context which defines, in part, an important American educational possibility. Simply stated, American education since its founding has utilized resources beyond the school--museums, factories, universities, churches, family--to forward a child's development. These agencies external to the school have in varying degrees and formats supported and rendered critical service to schools and their clientele, either complementing the school's efforts or providing an alternative to students and their parents when the school could not adequately respond to a demonstrated need (for a more comprehensive treatment of this issue see "Early Instruction by the College: Johns Hopkins Center for Talented Youth" by William G. Durden in *College-School Collaboration: Appraising the Major Approaches,* ed. William T. Daly, Jossey Bass, Inc., Publishers, San Francisco and London, 1985).

The Talent Search concept represents a vivid example of the supportive role which universities can play in advancing education for American precollegiate youth. In delineating this supportive function of the Talent Search, I shall use for reference The Johns Hopkins University Center for the Advancement of Academically Talented Youth (CTY), the oldest Talent Search initiative in the country as well as Duke University's Talent Identification Program (TIP), the second oldest Talent Search initiative. I believe these programs represent singularly and collectively the most complete testament to the supportive role of Talent Search initiatives.

Before proceeding it is perhaps helpful to state those defining characteristics which defines a Talent Search. Essential elements are a university base; a two-stage identification process (in-grade and out-of-level) that is regional in nature and that concentrates upon academic abilities; weekend or summer academic programs to include a residential component; and, a research agenda. The Talent Search's supplemental activities involve all four of these defining characteristics. At present four universities qualify for consideration--The Johns Hopkins University, Duke University, Northwestern University and the University of Denver. Each of these universities conducts independent Talent Search operations and therefore is in no way formally associated through a National Talent Search Consortium. They do, however, respect each other's area of regional Talent Search activity.

CTY-A General Description

The Johns Hopkins University Center for the Advancement of Academically Talented Youth has gained national and international recognition for identifying and educating mathematically, scientifically and verbally able youth. In 1971 the

University pioneered a successful method of finding and helping talented adolescents with the founding of the Study of Mathematically Precocious Youth (SMPY). Today, the Johns Hopkins Talent Search model and the academic programs developed by CTY have been replicated in other schools, colleges and universities both in the United States and abroad. The rationale underlying CTY's effort is based on three beliefs:

1. That talented youths should have an opportunity to fulfill their intellectual aspirations regardless of the age at which their abilities first appear
2. That those talented youths should have an opportunity to advance educationally according to their individual rate of learning and level of performance
3. That talented youths should have access to appropriate curricula that have been organized to respect a natural sequence of learning

This rationale is reflected at CTY in a comprehensive educational support system for academically highly able youth, consisting of four key initiatives:

1. A program policy statement
2. An annual Talent Search and recognition process for seventh-grade students in public, independent and parochial schools
3. Academic programs for precollegiate youth on weekends during the fall and spring and for extended lengths of time during the summer
4. A research agenda.

The comprehensive program also provides a series of supplemental services, to include by-mail academic programs, an Advising and Advocacy Service, international initiatives, young student classes (ages seven to eleven), minority outreach and access programs, consultation services and public policy, student/teacher recognition and training programs, a Parent Outreach Network and credit/placement coordination with a student's regular school program.

Educational Support Systems for the Academically Talented

Program Policy

CTY, established formally in 1979 by Dr. Steven Muller, President of The Johns Hopkins University, is an academic center with offices in Baltimore, Maryland and Los Angeles, CA. Its activities, CTY believes, are rooted firmly in defining characteristics of American education. This definition, from which much of recent education has strayed, is distinguished by a delicate balance of flexibility and autonomy for the individual learner with an imperative for equal opportunity of education among students with a wide diversity of need and ability. Exercise of these defining traits distinguishes institutional learning in the United States from that of all other countries where education is also a matter of national concern.

The following program policy defines CTY's work in general:

- CTY's primary function is to focus upon the institution of schooling as the principal form of advancing a youth's education and to ensure that that schooling is responsive to a maturing talent. CTY, therefore, does not offer a prescription for success in life; rather, it advocates responsive and appropriate schooling.

- CTY does not use the word "gifted" when referring to the children and youth with whom it deals. The word "gifted" should be reserved for that individual who has truly made a significant and mature contribution to the advancement of knowledge or practice.

The following policy defines CTY's work in identification:

- CTY focuses upon the identification of children and youth demonstrating high capacity in verbal and/or mathematical reasoning abilities. CTY, of course, recognizes a wide array of other talents a person could possess, but, it has chosen to limit its pursuit. CTY applauds those institutions which focus responsibly on other talent areas and sees them as necessary for providing a complete array of services for youth.

- Verbal and mathematical reasoning abilities form the focus of CTY activity for the following reasons:

    - They represent core abilities that are highly applicable to other areas of learning and pursuit.

    - They represent essential talents which inform those school subjects and related activities necessary for success in learning.

    - They can be efficiently and economically developed within the institutional setting of most schools regardless of their location or cultural resources.

    - They are more readily identifiable and less elusive than other types of talent.

- In identifying students with high capacity for verbal and/or mathematical reasoning abilities, CTY recommends a two-stage process: general screening and in-depth differentiation. The initial stage determines *the type* of talent exhibited by outstanding ability at grade level; the latter stage determines *the degree* of talent within an individual as a result of "out-of-level" testing. Out-of-level testing as opposed to grade level testing permits a high enough ceiling to discriminate diverse degrees of ability among extremely bright students.

The following policy defines CTY's work in academic programs:

- Students proceed educationally according to their demonstrated pace and level of learning

- The provision of appropriate subject matter (i.e. "enrichment") cannot occur without the provision of appropriate pace (i.e. "acceleration")

- CTY focuses its educational agenda on the liberal arts (i.e., English, history, foreign languages, mathematics, the sciences and the arts) as the most engaging and, in the long run, most valuable curricular embodiment of verbal and/or mathematical reasoning abilities.

- In a particular subject students are often examined before instruction begins to determine what they already know in order that the instruction which follows may emphasize what is clearly not known. Pre- and post-testing are critical elements of CTY policy and practice and can eliminate unnecessary boredom for students resulting from unwarranted repetition of skills and content.

- CTY balances rigorous and challenging educational course work with a social experience that encourages a realistic assessment of learning, enthusiasm and self-confidence.

Talent Search

The CTY Talent Search is conducted in Alaska, Arizona, California, Connecticut, Delaware, Hawaii, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Oregon, Pennsylvania, Rhode Island, Vermont, Virginia, Washington, West Virginia and the District of Columbia. Duke University conducts a Talent Search for the same age group in sixteen states: Alabama, Arkansas, Florida, Georgia, Iowa, Kansas, Kentucky, Louisiana, Mississippi, Missouri, Nebraska, North Carolina, Oklahoma, South Carolina, Tennessee, and Texas. CTY also sponsors an International Talent Search, which provides an opportunity for American and English-speaking students abroad to become part of the CTY network of academically talented students.

The Talent Search focuses on students who score in the upper three percentiles in mathematical and/or verbal reasoning as measured by standardized aptitude and achievement tests and who then sit for the College Board Scholastic Aptitude Test (SAT). CTY has just completed the largest search in its history. Approximately 36,000 seventh-graders registered for the 1988 Talent Search. Eligible students who cannot afford the fee to enter the Talent Search may be granted a waiver. In 1987 CTY granted about $8,000 in fee waivers. Duke University encourages qualified students to sit for either the Scholastic Aptitude Test (SAT) or the ACT Assessment (ACT). [In 1987, 41,309 students participated in the TIP Talent Search.] In order to ensure that all qualified youngsters have a chance to learn more about their potential, TIP also distributes fee grants to economically disadvantaged youth.

Each year the CTY Talent Search culminates in a series of awards ceremonies held to honor the top-scorers in each of the nineteen states where the search is conducted. The awards ceremonies are part of the CTY effort to recognize and foster academic excellence. Speakers at these ceremonies have included state governors, U. S. Senators, and national leaders in the sciences and humanities who have devoted their time to encourage talented youth people to develop their full potentials. Duke holds similar state ceremonies as well as a grand regional recognition ceremony on the Durham Campus of the University.

Many selective colleges and universities have donated one-course scholarships to be awarded to CTY top-scorers in their states. In addition, students who qualify for the National Talent Search by scoring 700 SAT-M or 630 SAT-V before the age of thirteen are awarded scholarships (totaling over $8,000 in 1986, for example) to be applied to CTY Summer Programs. These scholarships and other special honors are presented at the state awards ceremonies.

The CTY Talent Search also offers Career Symposia designed to help Talent Search participants develop career goals, College Counseling Days to assist these students in making informed decisions about the selection of colleges and Special Interest Days that permit students to focus on an area of study such as science, writing or mathematics. This year, for example, Career Symposia were held at the American Museum of Natural History in New York City, at the Boston Museum of Science, at the California Museum of Science and Industry in Los Angeles, and at The Johns Hopkins University in cooperation with the Maryland Academy of Sciences.

Academic Programs

CTY has emerged during the last decade as a national and international focal point for the education of highly talented youth in mathematics, the sciences and the humanities. The outstanding feature of CTY's programs, shared by TIP's programs, is the opportunity students are given to study challenging subject matter and to advance through an intensified curriculum. The classes are demanding and especially designed to match the intellectual requirements, academic needs, and developing potential of talented adolescents. For many, it is the first opportunity to match achievement with ability.

While participation in CTY programs can result in early college admission for some highly qualified students, this is not the chief goal of the program. CTY students typically enter college full-time at the usual age, but often with advanced standing in specific subjects.

CTY's courses are offered during the summer only at four residential sites and three commuter sites throughout the continental United States. An international site is proposed in Geneva, Switzerland in 1989. CTY's courses are based upon fourteen years of study, evaluation, and experience. CTY summer course work spans the humanities, mathematics, computer science, the social sciences, and the sciences, including distinctive science courses offered in cooperation with the Maryland Academy of Sciences. Classes are small and geared to students' abilities allowing individual attention and evaluation. A high degree of motivation and self-discipline is necessary to complete the daily class and homework assignments.

The atmosphere at the CTY Summer Programs is similar to that of a small college where academic pursuits are the primary focus. A safe and pleasant environment is created, geared to the special needs of a population of students whose ages range from twelve to sixteen years. Although academic pursuits are the principal considerations in CTY programs, students and parents have frequently told CTY staff that the social and extra-curricular activities which we provide for our participants are of great importance to them. The daily schedule is designed to permit a healthy mix of class work, study, athletics, activities, and social relaxation.

In 1987, 3,000 students attended CTY summer programs and came from 43 states and twelve foreign countries.

A supplemental goal of CTY course work is to permit students at an important period in their lives to develop lasting enthusiasm for learning as opposed to an environment sometimes hostile or indifferent to their talents. Selected comments from former CTY students vividly outline the contrast between CTY learning and that in their regular schools.

> In regular school, my progress was hindered by unchallenging curriculum and undemanding teachers . . . Since my regular school teachers never modified the curriculum, I was never motivated to learn. I just sat there, didn't try, and rolled in straight A's.
>
> [At CTY in contrast to my regular school] I didn't have to pass myself off as a less intelligent and a less unique person for the sake of fitting in. I wasn't discriminated against because of my age, grade, or what I wore.
>
> [In my school math class] even though I was placed in the top math class, the pace was too slow.
>
> [In CTY mathematics] no one ever told you what to do with every single step while never explaining why, so all that you ended up doing was strictly mechanical with no thought involved. Likewise there was no one standing over you saying, "My way is the only way to do this, if you don't do it this way, you're wrong."
>
> [Most of my regular school work] is regurgitated bit of information copied quietly off the blackboard . . . learning is a chore.
>
> In my high school [because I like math], I'm a "brain", a freak . . . In school so few people take any real interest in what is being taught.
>
> Everyone in our [CTY] class felt free to ask questions, even if they were off the subject, without fear of derision. Unfortunately, in some schools, this is not the case; students are repressed and bored as a result of conforming to the mind-set of their classmates.
>
> In school, things have always come easily, with no real effort at all. A parroting back of facts is considered insight, a grammatically correct paragraph is seen as literary genius. I have always done what is expected of me, only at school the expectations are ridiculously low.

> When I first came to CTY, it was the first time that I had to work for something. Suddenly, the "challenges" were challenging and the "demands" were demanding. It was hard, and a few times I failed but, I learned. For the first time in my life, I learned, not only about writing, but about working.

Students who exhaust CTY offerings can take advanced courses in their local high schools, in universities or can enroll for a Summer Residential Honors Program for sisteen and seventeen year olds conducted by The Johns Hopkins School of Continuing Studies (on the Homewood Campus of the University) and offering college credit.

Duke University offers on the Durham Campus both a TIP Residential Program for twelve to sixteen year olds (college credit or non-college credit) and a Precollege Program.

The Summer Residential Program, much like the CTY Program, offers intensive, fast-paced courses in the humanities, social sciences, natural sciences, mathematics, and computer science. Students enroll in a single course during a three-week term and generally complete the equivalent of a year of high school or a semester of college-level work. The Summer Residential Program is open to students who have completed grades seven, eight, nine, or ten. The Precollege Program is open to students entering their senior year and to those students entering their junior year who have received an "A" or "B" in a TIP college-credit course. Precollege students enroll in two Duke Summer School courses with regular undergraduates and earn college credit.

In contrast to CTY, which no longer offers academic year commuter programs, TIP offers a Commuter Program as an enrichment experience for students who live near enough to Duke to commute. The purpose of the program is to present a high-level introduction to a variety of topics and issues. It is not intended to provide high school or college credit.

Enrollment in the TIP Summer Residential Program has also been substantial. In 1987, 814 students were in attendance.

Credit/Placement - Coordination with the Student's Regular School Program

CTY cannot award credit or placement for CTY courses, even if the content is equivalent to or more advanced than that available to the student at the local school. CTY makes concerted efforts, however, to facilitate its students obtaining credit and/or placement.

CTY strongly recommends that before students register for courses, they take the CTY summer catalogue to their local school principal and/or guidance counselor and discuss the effect their plans may have on their future academic endeavors. CTY also helps in negotiations with schools for appropriate course placement and credit for academic work completed with CTY. Because students come from hundreds of local schools and school systems, CTY staff members cannot directly speak with officials from each school. CTY has found, however, that those students who conclude arrangements with their schools before attending CTY classes and who bring descriptions of course work and all CTY records of accomplishment to the schools, often receive appropriate placement and/or credit. Upon completion of a CTY course of study, each student receives a course description and a detailed, descriptive evaluation of his/her performance. This evaluation is written personally by the student's instructor and focuses on academic performance and overall progress and effort throughout the session. The evaluation is addressed to the student and is formal in tone. Topics for discussion are content-centered and are specific enough that educators outside CTY are able to infer the high level at which the course was presented and be able to measure a student's achievements by their own standards. This evaluation is accompanied by nationally-normed, standardized pre- and post-testing results, when appropriate and a recommendation for the next logical course of study following completion of the CTY experience. To assist teachers in the local schools to anticipate the general recommendation of subsequent course taking following specific CTY subjects, CTY has published a document entitled "CTY Guidelines for Credit/Placement - Science/Mathematics and Humanities." In addition, CTY conducts an annual survey of selected students following the summer program to assess the status of credit and/or placement issues in the schools.

Duke University possesses a similar disposition towards coordination with a student's regular school program as does CTY. Duke University as Johns Hopkins does not have a laboratory school nor a Department of Education. The Talent Identification Program is not prepared nor does it desire to compete with the public, independent or parochial school. One goal of the Duke effort is to be seen as a resource for schools as they develop challenging educational plans for their most brilliant youths.

After students have completed TIP summer programs, a detailed test report and academic evaluation are forwarded to both the student and school. Recommendations for placement and suggestions for other educational activities are provided which would benefit the student. A new staff position, Associate Director for Student Services, has been created. This full-time professional serves as a liaison among the program, students, the school and the parents of the participants.

By-Mail Programs

The writer/apprentice correspondence relationship is one of the great traditions in classical education, dating back to Roman antiquity. It is also one that in recent years has been largely abandoned in favor of large-scale education efforts, when often too little energy is reserved for serious, lengthy communications between teachers and students.

The CTY Expository Writing Tutorial-By-Mail (EWT) reclaims this literary tradition. Instituted in 1984 with a grant from the National Endowment for the Humanities, EWT has set in place a forum for communication between the apprentice and master writer, where the tutor responds with extensive personal comments about student work.

Since the program's inception, nearly 1,000 students have participated in this valuable opportunity, practicing writing and building upon previous lessons. The curriculum is straightforward--every 10 to 14 days, students receive a letter and a new writing assignment. The letter comments on the student's previous work, offers constructive praise, and makes supportive suggestions for improvement. New assignments stem from the tutor's diagnosis of a student's needs. For example, one typical assignment sequence guides the student from simple description of surroundings, to self-description from another point of view, to using another persona to narrate an event, and finally to an analysis of an event or situation.

Like other CTY courses, EWT is a multi-leveled program. Every phase allows students to exercise their proficiencies while learning new skills. EWT sequences are available for three levels of sophistication: students who have never taken a CTY Writing Skills class; students who have completed one or more CTY Writing Skills classes; and students ready to prepare for the Advanced Placement Examination in English Language and Composition.

Most EWT tutors are professional writers trained in teaching writing. Many hold advanced degrees from the most outstanding writing programs in the country. Many have taught CTY Summer Residential classes and have also published short stories, magazine articles and poetry in regional and national publications.

Two hundred and fifty five students are enrolled in the 1988 CTY/EWT Program.

During the academic year TIP runs an extensive "By-Mail" program. The "By-Mail" courses provide a challenging learning experience for academically able students with well-developed independent learning skills. Students are provided with college-level texts, supplemental materials, and in some cases taped lectures. An assigned mentor guides students, grades their work, and serves as a long-distance resource. Some of these courses prepare students to take College Board Advanced Placement examinations and thereby enable them to earn college credit for their course work. "By-Mail" courses are open to students in grades 8-12 and are particularly helpful to rural students. Two hundred and thirty-six students took part in the program in 1987.

The Advising and Advocacy Service

CTY's emergence as a national and international pioneer in the education of talented youth places it in a position to assess comprehensive needs in the field and to provide accurate information to parents, students and educators.

Through a grant from The Lynde and Harry Bradley Foundation, the Advising and Advocacy Service was established in January 1988 to provide information on programmatic, personnel and material resources and to provide needed educational services.

The Advising and Advocacy Service functions as a central clearing house for information on programs, organizations, opportunities and resources that are useful to academically talented students, their parents and interested educators. Bibliographies are available to inform parents and educators about the issues and practices in the education of highly able students and to help researchers locate information on topics of interest. Special bibliographies on such topics as talented girls and talented, learning disabled students are also available.

In collaboration with other experts, CTY staff members have developed written responses to frequently asked questions. (CTY, for example, receives some 5,000 telephone calls per month seeking information). These responses clearly reflect the CTY philosophy that early identification and educational intervention are essential to ensure that highly able youth will reach the highest levels of their intellectual potential. Guidelines to help parents evaluate programs and opportunities that are available for their child's education are among the many documents available. Issues surrounding identification and appropriate educational planning are also discussed.

And finally, quite often local school systems need help to develop programs or modify existing courses to accommodate better their most academically able students. Curricular packages and consulting services are available to aid schools and individuals in their efforts to provide appropriate educational experiences for academically talented youth.

Duke University responds to the need of public awareness in a variety of ways to include *The Educational Opportunity Guide*, published annually and listing more than 350 programs for highly able children and youth.

International Initiatives

CTY serves the education of highly able children and youth internationally in a multifaceted manner:

1. The Director of CTY, under contract to the Office of Overseas Schools, U. S. Department of State, evaluated in 1986 the quality and extent of educational programs for highly talented youth in American-sponsored schools throughout the world. As a result of recommendations issuing from this study, the U. S. Department of State established a National Advisory Committee on Exceptional Children and Youth whose purpose is to counsel American-sponsored overseas schools on educating highly able youth. Dr. William Durden chairs this committee and CTY serves as the professional resource organization. A model school program has already been established in Sao Paulo, Brazil.

2. CTY conducts an annual International Talent Search for seventh-graders or students of seventh-grade age.

3. CTY announces the establishment of its first international summer residential program at the College du Leman, Geneva, Switzerland. Beginning in 1989, this international center will accommodate overseas students as well as stateside students.

4. CTY and the University of Hamburg, the Federal Republic of Germany, are entering their fifth year of a cooperative service/research project. Hamburg under the auspices of this agreement has developed special weekend mathematics and writing courses for highly able German youth and in 1988 will open the first German summer residential program for youth highly capable in mathematics. Faculty will be Germans who have taught for the

last three years at CTY summer sites in the United States through a Hopkins/Hamburg faculty exchange. The CTY/Hamburg project has also resulted in at least twenty research papers and master degree theses in Germany.

5. CTY and the University of Tel Aviv are currently negotiating a summer exchange of students. In the summer of 1988, TIP and the University of Ulm will embark upon an exchange program that will enable five students to study advanced mathematics at a foreign university. Duke will be host to five German students and in turn the Universities of Ulm and Konstanz will welcome five TIP students to participate in their Intensive Mathematics Program for academically talented high school students.

TIP students will also have the opportunity to continue their study of Chinese in Beijing, China. The program will combine intensive language instruction at Beijing Teacher's College with formal and informal opportunities to study the culture and society of this important nation and culminate in a study trip to other cities.

Young Students Classes

CTY has initiated a pilot program for students in the elementary grades: second through seventh grade. Students are identified with an out-of-level test, the School and College Ability Test (SCAT), which measures their mathematical and verbal reasoning. The classes focus on adjusting important aspects of the students' education, particularly the pacing and level of instruction, to meet the students' assessed needs. Young students are encouraged, as soon as they are ready, to begin mastery of the necessary fundamentals of scholarship and to find expression for their excellent reasoning abilities.

During the summer, classes meet three hours per day, five days per week for three weeks, at sites in Baltimore and Columbia, Maryland.

The Academic Year Program offers classes in Baltimore and Columbia, Maryland and Richmond, Virginia. (In the fall of 1988 CTY will begin classes at the new Hopkins Center in Montgomery County, Maryland.) Classes meet for two and a half hours once each week from October to Mid-May.

Course offerings include Self-Paced Individualized Arithmetic/Pre-Algebra/Algebra, Reading in the Classics, Basics of Writing, Latin for Language Development, Mathematical Problem-Solving and Science Exploration (focusing on Biology and Chemistry).

Minority Outreach and Access

CTY with the generous assistance of numerous foundations has initiated an extensive effort to improve academic access and accomplishment among minority youth. This effort manifests itself in various ways:

1. Initial Outreach: Through the funding of outreach representatives in selected urban areas, CTY is working to bring forward those young minority students

who are currently eligible for the CTY Talent Search but for various reasons are not coming forth.

2. Skills Reinforcement Project (SRP): CTY is involved in a three-year project to promote the enrollment of minority and economically disadvantaged youth in programs for high academic achievement. With grants from a variety of private foundations, 42 sixth-grade students in the first year of the project, representing the ethnic diversity of the Pasadena (California) Unified School District (76 percent minority, with 41 percent black and 26 percent Hispanic) have been involved in a nine-month skills reinforcement program. The program is designed to develop the students' verbal and mathematical reasoning skills and to improve their study skills, so that they can meet initial qualifying scores necessary for competition in the CTY Annual Talent Search (97th percentile on an in-grade achievement test in either the mathematics or verbal area) and/or qualify for local gifted and talented programs. Students were selected on the basis of their performance on the California Achievement Test (CAT). They must have scored between the 80th and 96th percentile to have been eligible.

A premise for the program is that with proper assistance minority students can meet the standards set for "advantaged" children. Students in the SRP participated in a three-phase, intensive academic program which involved:

- Twelve Saturdays from February through May, 1986
- A two-week residential program in coordination with CTY Summer Programs
- Eight Saturdays from October-December, 1986. The students took the CAT tests in the fall. The preliminary results are promising: 20 of the 42 students scored at or above the 97th percentile in *either* mathematics or reading. The second year of the project with a new group of students was equally successful. A third replication of the SRP, with yet another group of students is currently underway

CTY is delighted to announce that as of January 1, 1988 The James Irvine Foundation (California) has funded CTY to bring the Skills Reinforcement Project to Los Angeles Unified School District.

3. The Jerome "Brud" Holland Scholarship Program: CTY announces a new scholarship program that will make substantial funding available to qualified students (especially minorities, women in mathematics/science and students from rural areas) who might otherwise be unable to participate in the CTY Talent Search and/or CTY Academic Programs.

Funding available under this program will pay the SAT registration fee for students who have registered with the Talent Search under the CTY provision for partial fee waivers and will provide partial to full tuition grants and assistance with such costs as travel expenses for selected students who qualify for CTY summer residential programs regardless of race, religion, or national origin. The academic program grants may be single or multiple year. The program is named in honor of the late Dr. Jerome H. (Brud) Holland.

Dr. Jerome H. Holland, a graduate of Cornell University (B.A. with honors, 1939) and the University of Pennsylvania (Ph.D., 1950), was an educator, civil-rights advocate, and former United States ambassador. One of thirteen children of Robert and Viola Bagley Holland, he began working for his father, a gardener and handyman, at the age of eight. Arriving early in life at a strong belief in education and job training as the key to advancement, Dr. Holland later became president of the Hampton Institute and president of Delaware State College. He served on the board of directors for the United Negro College Fund, and in 1965 was elected to the National Football Hall of Fame. In 1970 he was named Ambassador to Sweden, and he served as chairman of the board of governors of the American Red Cross, a member of the board of directors of the National Urban League, and as a director of fourteen corporations including the American Telephone and Telegraph Corporation, the Chrysler Corporation and the General Foods Corporation.

4. Independent School Admission and Scholarship Program: CTY has established in cooperation with several independent secondary schools a distinctive program that permits qualified minority youth involved in CTY programs to be admitted and to receive scholarship assistance. Among the participating schools are the Harvard School (Los Angeles, California) and the Newark Academy (Livingston, New Jersey).

Duke University also devotes considerable resources to the issue of minority participation. Increasing numbers of minority students have gone through the identification process, which remains the typical introduction of students to TIP's other programs. With extensive foundation support, minority representation in the Summer Residential Program has steadily and dramatically increased from 1 student in 1981 to 87 students in 1987. In addition, major scholarship support for women, minorities, and rural youth has come from a variety of foundations.

Consultation Services and Public Policy

CTY provides consulting services to advance the quality of academic services to youth. CTY has worked at the local school, district, county, state, national and international levels to help evaluate the current status of efforts for highly able students and to provide a plan of action based on CTY's philosophy and practice. Current efforts include work with the New York State Science and Technology Foundation; the Wisconsin Institute on Public Policy; the Appalachia School District, Pennsylvania and the Baltimore City Public Schools.

CTY consulting service is informed by several implications emanating from its distinctive program policy. Among these are:

- While CTY concentrates for reasons of organization, economy, and efficiency upon academically able children and youth, it believes strongly that with appropriate adaptation and adjustment its policy and practice are applicable to a much more diverse group of students.

- Schools should not bear sole responsibility for the nurturing--both educational and emotional--of children and youth. The imaginative use o[illegible]r institutions, to include the family, museums, universities, clubs a[illegible]rches, contributes decisively to meeting the challenge.

- [illegible] no *one* program that meets the needs of all academically able y[illegible]ther, a variety of responsible strategies are appropriate.

- The artificial lock-step of education (kindergarten through graduate school in discrete units and in predetermined progression) should give way as much as possible to allow students to progress at their own rate in particular areas of study. Students, therefore, could be placed simultaneously at various levels of instruction depending upon the development of talent in a particular subject area--mathematics, science, English, foreign language, history and the arts.

- Talent needs information. Not to introduce and discipline highly able children and youth in the initial levels of cognitive ability (such as defining terminology and symbols; recalling facts, names, examples, rules and categories; recognizing trends, causes and relationships; acquiring principles, procedures, implications and theory), as well as the highest levels (evaluation, synthesis and analysis), is to render them unprepared for sustained intellectual and creative contribution in later life.

- Those qualities such as creativity, problem solving, risk taking and critical thinking, naturally associated with the unfolding of high level verbal and/or mathematical reasoning abilities and found within those core school subjects--such as mathematics, language arts, foreign languages, science, history and t generally best taught, however, in an integrated fashion, embedded in appropriate subjects of the liberal arts curriculum, rather than as a separate course.

- Course work for highly capable students should not be of a "make-more-work" nature. The course work should either assist those students with identified need to proceed more efficiently through a regular course of study or offer relevant and challenging enrichment which will extend knowledge systematically in a target area of the curriculum or in an associated interest.

A more detailed commentary on selected CTY consultation projects follows:

1. *Appalachia Intermediate Unit, Edensburg, Pennsylvania:* With the assistance of CTY staff, the Appalachia Intermediate Unit School District is in its third year of a Mathematics Project. The Project includes grades 2 through 8 but aspires to establish a flexibly-paced mathematics curriculum for kindergarten through senior high. A significant impact on the mathematics' instructional programs and on student achievement since the establishment of the project has been empirically documented. Achievement gains were immediately evident and have continued to increase. Several of the students participating in the Mathematics Project have won mathematical awards and honors on regional, state and national levels.

- The project has attracted national and international inquiries. The most conspicuous include Dr. Harald Wagner of the German Association "Bildung and Begabung," June Cox of the Richardson Foundation and Pat Tierney of the Pittsburgh City Schools.

2. *Cooperation for Success in Mathematics:* CTY plans to join with the Roland Park School, a part of the Baltimore City Public Schools, to initiate a pioneer effort to implement CTY's distinctive approach to the instruction of mathematics in a regular public elementary and middle school setting. Such an effort not only maximizes the vital cooperation of public and private institutions as well as a unile school setting. Such an effort not only maximizes the vital cooperation of public and private institutions as well as a university with a pre-collegiate school, but also applies systematically those methods of instruction that have demonstrated effectiveness with talented youth upon regular students. In addition, CTY welcomes an opportunity to offer the students of Roland Park School the opportunity to have within their own institution a choice in instructional format which may in some cases result in increased commitment to and motivation for education and heightened performance in mathematics. A research design shall be utilized to test the effectiveness of the CTY model as compared to the school's existing traditional instructional format.

3. *CTY Individual Assessment and Evaluation Opportunity:* Highly able students and their parents often do not have sufficient information to participate fully in important educational decisions. Students attending the Carlisle and Lancaster, Pennsylvania CTY summer residential sites are offered the opportunity to learn more about their educational profiles as they prepare for college and career decisions.

   Participants who opt for this service receive:

   - An assessment package to help them and their parents make more informed decisions about career, college and current educational choices;

   - Two group interpretation sessions (one designed for parents and the other for students) to explain the testing results and how this information can be used; and,

   - A complete profile for future decisions and counseling. The assessment package presents a profile of the student's learning style, interests and personality traits in a positive and constructive manner. Students are encouraged to examine how their respective patterns of preferences, traits, and styles influence how they learn. They also analyze their interactions with others, their educational and career choices, and traits that can help them attain their goals.

Duke University has also pursued an active agenda of consultative outreach and service. TIP hosts an annual conference for state-level G/T Coordinators throughout its Talent Search Region; it has established a cooperative program with

Western Kentucky University; it provides regularly consultation to public and private schools; and, it developed Advanced Placement supplementary materials through a grant from the Mary Reynolds Babcock Foundation which are now in at least one school in each of the fifty states. More than 3,000 copies of these materials have been sold at cost of publication.

Student/Teacher Recognition and Training

CTY through substantive funding opportunities has advanced a variety of innovative student and teacher recognition and/or training programs. Some of these efforts are highlighted below.

1. *The Orville and Irene Anderson Excellence Awards for Young Scholars and Recognition Awards for Local Educators:* This is a unique program intended to emphasize academic achievement and motivation among CTY program participants. The Orville and Irene Anderson Awards provide the recipients with scholarships to the college of their choice, and recognize the outstanding support provided to these young people by their educators.

At each CTY summer residential site, some students are nominated by the faculty for their outstanding academic performance and motivation. These nominees are then invited to submit an essay describing what CTY's summer programs meant to them and outlining their future educational plans. Two first-award recipients, two second-award recipients, and two third-award recipients are selected by CTY to receive scholarship support towards their college education. First and second-award recipients and their families are also asked to nominate the educator who most influenced them. These educators are invited to attend a special Recognition Ceremony held in Baltimore, where they are honored by educators from throughout the Johns Hopkins' community as well as through citation from their respective state governors and U. S. Senators as well as the United States Secretary of Education.

2. *SDB Foundation - Teacher Recognition Program:* With funding from the SDB Foundation, CTY intends to advance significantly in the state of California the identification and recognition of elementary school teachers with affirmed commitment to high standards of instruction and respect for the emerging talents of highly capable youth. Such an agenda represents unprecedented action to applaud and advance those dedicated teachers who have so long been laboring in relative obscurity, but whose talents, successful practices and point of view demand an appropriate forum for influencing the well-being of American education. Proposed projects to be conducted under the grant treat two discrete topics:

- A recognition process and award ceremonies (in San Francisco, Los Angeles and San Diego) for outstanding elementary-level teachers/administrators brought to CTY's attention through nominations by students and their families who are selected as state/regional award winners in the CTY Annual Talent Search for seventh-graders.
- A one week summer recognition institute for fifteen (15) selected teachers/administrators who were nominated for citation by student Talent Search award winners for the state of California. Such an

Institute will not only provide CTY with more information about the profile of an outstanding teacher/administrator for talented youth which will in turn assist schools throughout the country in discovering appropriate instructional talent, but also, will give the educators a recognition so infrequently bestowed.

3. *National Endowment for the Humanities Teacher Training Institute:* Forty-eight elementary and secondary teachers and administrators from four areas of the country came together in the summer of 1985 to study writing (CTY has published a distinctive book on teaching writing for highly able youth-- *Writing Instruction for Verbally Talented Youth:* The Johns Hopkins Model by Reynolds, Kopelke, Durden, Aspen Systems Corporation, 1984) and etymologies. Educators from Saratoga Springs, New York; Phoenix, Arizona; New Brunswick, New Jersey, and the Greater Los Angeles Unified School District studied for three weeks at the Dickinson College site in Carlisle, Pennsylvania. They studied the relationship between writing and word origins, both of which are a part of the regular CTY curriculum. In 1986 a select group of the participants spent one week developing materials adapting this curriculum for their home schools. The results of this work are published in a text entitled, *Affinities: Varieties of a Writing/Etymologies Curriculum for Precollegiate Youth,* edited by William G. Durden and Elizabeth B. Carter.

4. *Overseas Schools Summer Training Seminar:* CTY will conduct a stateside ten-day residential teacher training seminar for staff of American schools in Mexico, Central America and Colombia in 1989. This seminar is preceded by workshops in Sao Paulo, Brazil; Cali, Colombia; and, Santiago, Chili.

Duke University has also initiated several innovative teacher training efforts. Through a grant provided by the Mary Reynolds Babcock Foundation, a pilot effort involving student/teacher instructional teams was initiated in 1983. The concept involves students enrolling in the Summer Residential Program and their teacher serving as a teaching assistant in the students' class. Both student and teacher study with one of the program's master teachers. All curricular materials are available to the participating teacher. Upon completion of the Summer Program, the student/teacher teams return to the local school where the teachers resume their instructional duties and the students serve as a teaching assistant for one period per day. The initial team came from McAllen, Texas Independent School District.

Parent Outreach Network

As part of the CTY Talent Search's ongoing effort to improve the range and quality of services offered to Talent Search participants and their families, the Parent Outreach Network was officially formed for the 1987 search with funding from The William Bingham Foundation.

This organization consists of parents who volunteer to contact schools, answer questions for their respective state from parents and teachers by phone and to hold informational meetings in local communities. The Parent Outreach Network proves a highly effective means of communicating the CTY message. Parents whose children have participated in the Talent Search and Academic Programs are particularly credible representatives of our organization. Outreach volunteers are very active on behalf of the Talent Search and effectively support professional CTY staff by helping to arrange Awards Ceremonies, conducting the ceremonies, placing stories in local newspapers, advising concerned parents of options for educating highly capable children based upon personal experience and encouraging local schools to join the Search.

Duke University also has an active Parents Network. In order to open opportunities for academically talented students beyond the Duke campus, TIP has started a Parents' Network which acts as a conduit of information from the program to parents, from parents to parents, and from the parents to the program. In the short history of the Network, parents have presented seminars about the Duke program at state gifted education conferences and have sought to change inappropriate local policy.

Research

Since CTY's inception, it has worked incrementally to reach through Talent Searches, academic programs and supplementary activities as many students and their families as possible. But during that period, through lack of funding and time, CTY did not have the opportunity to conduct a substantive research agenda although much of the data that could underline such a program was collected and internal evaluative documentation was consulted for academic program direction. (Initial research upon the validity of the Talent Search Model was conducted by Dr. Julian C. Stanley, founder and director of the Study of Mathematically Talented Youth, The Johns Hopkins University.)

Within the last year, CTY has turned its attention and resources to forming a substantive research agenda for the next decade and in so doing, to underscore the vital link between research and its future conduct of public policy. A university-wide Research Committee devoted exclusively to CTY was appointed by the Provost and Vice President for Academic Affairs and is chaired by the Vice Provost of The Johns Hopkins University. CTY has also appointed a Director of Academic Program Research as well as a Data and Testing Analyst. With this increased staff as well as with an intensified examination of the research potential of the Talent Search Division, CTY has begun in 1988 a one-year self study to formulate its research agenda, an agenda appropriate to its mission and capabilities. Already a number of discrete research projects are emerging to include a study of CTY's fast-paced science courses, conducted from 1982-88, a follow-up study to determine concretely the influence of the Talent Search and academic programs (mathematics, sciences and the humanities) upon the youth and schools in particular schools, an empirical assessment of an early intervention program for minority students and a testing of the validity of its entrance SAT requirements for its various courses.

Duke University/TIP finds itself in a similar stage of development with regard to research as does CTY. Thus far only modest effort has been expended on conducting sophisticated research with talented adolescents. Necessarily, during the initial years of the program the attention of the TIP Director and staff has been focused in developing and revising the Talent Search materials, initiating high quality and broadly based educational programs and developing the local institution support for the Duke effort. According to Dr. Robert Sawyer, Director of the TIP, it is now imperative for TIP to focus attention on developing high quality research projects that will serve the Program without distorting it. The research effort should strive to establish a knowledge base from which to continue the development of quality educational programs and services while simultaneously contributing to the general understanding of the talented students.

To this end, a National Advisory Committee was appointed to advise the Director on an appropriate research agenda and a local consultant group composed of Duke faculty and administrators provides assistance in the day-to-day operation of the evaluation effort. As with CTY, TIP research publications are beginning to emerge from the program. TIP's own research efforts along with a cooperative research program with Yale University produced a dozen publications or submitted manuscripts in 1986/87.

TIP is also currently involved in pioneering research with the ACT Assessment Program to break new ground in discovering how well the ACT measures academic skills of talented young students.

Conclusion

By using the examples of CTY (The Johns Hopkins University) and TIP (Duke University), this paper presents extensive and ambitious educational support systems for academically talented children. The sheer variety of the services and the number of students receiving benefits of the services (some 80,000 by both institutions in 1987 alone) argues for the unique place of the concept *Talent Search* in the history of American education. Making maximum use of inherent flexibility possible in schooling within the United States and of the autonomy available to the individual learner, CTY and TIP quintessentially demonstrate the degree to which American education can succeed imaginatively in advancing academic potential imaginatively. Of course, CTY and TIP as well as those other responsible Talent Search programs are not *the* answer to serving high ability among our children. No *one* program serves the needs of all youth. A variety of choices from magnet schools, to high quality teaching in the regular classroom, to specialized residential high schools are needed to match an individual student's ability with an appropriate institutional setting in which education can take place. But in an environment where autonomy and flexibility are highly valued educational capital, CTY and TIP offer far-reaching and comprehensive paradigms for advancing learning.

Discussant Reaction:
The Development of Educational Support Systems for the Academically Talented: The Talent Search Concept

Stephanie Marshall

My task as a discussant is to primarily focus on Dr. Durden's paper. However, I will also use his paper as a framework to talk about residential programs. Dr. Durden has given us a very rich and comprehensive review of the talent search program, its philosophical premises and its programmatic constructs. He's described in great detail the rationale, and what I will call the cognitive scaffolding that supports the talent search concept within the context of the two very critical values that characterize American education: programmatic flexibility and individual autonomy. He has reviewed the talent search concept as an example of an educational support system for the academically talented. As a discussant of Dr. Durden's remarks I want to comment on what I consider to be the fundamental philosophical premises of the talent search program as well as the principle programmatic components. I think this is important because this reflection will cause us to look at the talent search concept as an example of what all educational support systems should be that are designed to develop academic talent.

I also want to comment on some of the other critical dimensions in the talent search program; these include: 1) the identification/development of appropriate student/learner outcomes; 2) the issue of minority recruitment, identification and retention; 3) career exploration programs; 4) the social and emotional needs of gifted youngsters; 5) communication with their school program; 6) advisory advocacy services; 7) affiliations with local school districts; 8) the identification of very young and talented students; and 9) the recruitment, selection, induction, and retention, of faculty or, how to cultivate and keep remarkable faculty, which is one of the issues that we are working with at the Illinois Academy. In order to address these concerns. I'm going to draw from my background in gifted education, my background as the Director of an institution which is still in its infancy--we're only a year and a half old--and also my present role as chair of the State Board of Education's Advisory Council on Gifted Education, which is a statutory appointed committee by the legislature.

Dr. Durden has underscored the strong advocacy role that universities play in advancing education for talented youth as fundamental to the talent search concept. The involvement of universities in gifted education reinforces the concept of vertical integration that Al Trivelpiece spoke about. I support the four defining characteristics of the talent search program; I think they are fundamental and important as we begin to design educational support systems for gifted students. The university base; the comprehensive and two-stage identification process; the residential component which is critical not only for student interaction with mental age peers, but also for that "critical mass" of which Durden spoke; and the strong research base, because of the implications that will have for statewide and federal policy development. However, I want to focus my remarks on the belief system, because the most critical variable in the talent search program is that belief system. The belief system represents the fundamental construct upon which talent is based.

Progression is based on individual need and rate of learning and with content that can be differentiated to meet those individual learning needs. I'm familiar with the talent search program adopted by the state of Illinois, as well as the

Midwest Talent Search at Northwestern University. And as is true for the Center for Talented Youth Programs, these other programs are also based on the premise that school is the primary mechanism through which talent is advanced, and that opportunities presented through schooling must be individualized according to the student's rate and level of learning. This premise is manifested, I think, in the policy variables that define the CTY's work in academic programs. Enrichment and acceleration are both provided, indeed, Durden compared them to love and marriage. Pre and post-testing occur prior to instruction, and the focus of the educational agenda is on the liberal arts.

I want to address these variables now from the perspective of the Illinois Mathematics and Science Academy (IMSA) as a model of another kind of educational support system. I found this comparison particularly useful as I read Durden's paper many times to extrapolate the variables; the belief system, and the programmatic components of the talent search program. I wanted to use these components of the talent search program. I wanted to use these components also as a programmatic overlay by which to discuss other programs, which is to say a program that really works--and we have enough research to indicate that the talent search across the nation is working, not only in identification of talent, but also in providing programs --then how might I assess the program in which I am presently involved, using the same variables. The process would be very useful, not only to me, but perhaps to you, as you look at the talent search as a model, and then begin to develop from the model other kinds of educational programs to support gifted kids.

IMSA is a 3-year residential school for students gifted in math and science, very much modeled after the North Carolina School of Science and Mathematics (NCSSM). Borden Mace, who is sitting here, worked directly with us in the establishment and development of the Illinois Mathematics and Science Academy. I think someone mentioned yesterday that Borden has a hand in every residential school across the nation, and indeed that is true. We were certainly privileged to work with him.

The mission of our institution is to challenge and inspire students of rare talent in math and science; took on two goals within that context. One was to develop an outstanding academic program in math, science and humanities for students with extreme talent, the other was to serve as a laboratory for outreach in curriculum development across the state of Illinois.

I want now to begin to discuss some of the components in a very brief way to show you how the residential school concept begins to address the programmatic variables that Dr. Durden talked about in talent search programs.

Selection

David Perkins mentioned earlier that talent identification should focus on early achieved ability, and ability in a domain. Certainly Durden just described how verbal and mathematical reasoning ability constitutes the focus of the talent search program, they are also the focus of the IMSA and NCSSM as well. We use a system called accomplishment based assessment, where we look at what students have already accomplished within the context of the school environment from which they come. Illinois is a very diverse state; we have some very affluent areas, and we have some very poor areas. We border on Kentucky, Wisconsin, and the state is industrial and rural. For this reason we look at what students have already accomplished within the context of their home environment, what have they taken advantage of, what leadership opportunities have they utilized, and how have they demonstrated abilities in mathematical and scientific reasoning, communication skills, and general performance. We do use the Scholastic Aptitude Test (SAT), and we are screening approximately the upper one percent of the student population. We receive a student application, and recommendations of the math teacher, science teacher, principal, and guidance counselor. We look for descriptive information which Durden also considered significant in the talent search.

Student Learner Outcomes

We are in the process now of developing very general learning outcomes. We are fortunate because, we are not bound by school codes, and therefore we have what I consider to be remarkable opportunities to develop the criteria by which we will be judged. That doesn't happen very often in education. The broad student learner outcomes are directed by our mission statement. These outcomes are meant to answer for us, "What are the characteristics of the student for which we will be proud?" Maybe that simple, but that's essentially what we're looking for. When a student is engaged in problem solving in a particular enterprise, we want someone to say, "Now where did you come from? You can look at problems in different ways, you are exploring things in a different way, you are using your imagination, your intuition. Where did you come from?" So we began to identify those learning outcomes. We came up with 14. Now we're in the process of saying, "So What?" We have to take those student learning outcomes and find ways to facilitate these outcomes in mathematics, in science, in English, in foreign language, etc. Let me enumerate each one of the 14 outcomes.

1. The ability to formulate questions and seek answers through the observation and interpretation of phenomena.

2. To communicate effectively through the written and spoken word.

3. To solve problems and think critically in all areas of learning by analyzing, synthesizing, and integrating data.

4. To think creatively and innovatively.

5. To demonstrate the use of intuition and imagination in the generation and solution of problems.

6. To demonstrate research and investigative skills.

7. To demonstrate the academic and technical knowledge needed to fulfill civic responsibility, to improve the student's own health and life and to cope with an increasingly technologically complex world.

8. To judge the value and relevance in information in presenting conclusions.

9. To demonstrate a core of base knowledge and skills in all areas of learning.
10. To demonstrate a healthy and positive self-concept.
11. To demonstrate a sense of social awareness and responsibility.
12. To make decisions in a moral and ethical context.
13. To demonstrate the joy and excitement of life-long learning.
14. To demonstrate an appreciation of aesthetics based upon observation and perception.

Curriculum

The above goals may appear simplistic, but believe me, when you're working with the kind of staff that we're accustomed to working with at IMSA it takes a long, long time to reach agreement, especially when you know full well that once you put it down, you're going to have to do it. The curriculum, then, is obviously driven by those learning outcomes. The faculty is now developing the curriculum that will enable students to achieve these outcomes.

We see our students as apprentice investigators and scholars. I think that mind set is critical in the program itself. We're trying to develop an interdisciplinary and integrated program; that's less easy than it sounds. The only reason I think we may have a shot at it is because I do sometimes find English teachers in science teachers in German teacher's classrooms, etc., etc. We're trying to develop this interdisciplinary and integrated program because we believe this is the way knowledge is formulated and discovered by giving kids opportunities to be challenged. College Advanced Placement and becoming sophomores and juniors in college at an early age is really not our goal. We are working with enrichment combined with acceleration. You shouldn't have one without the other. We are also very lab oriented, and experiential. We are also in the process of developing a "tinker's room" just for kids to come in and "play," with electronic equipment, etc. We do think that's important.

Talent, of course, needs information--you do not create in a vacuum. In terms of curriculum development, our goals are very rigorous. We are working with the development of mentorship opportunities, graded and non-graded courses, Friday seminars, Saturday seminars, and lots of opportunities for the kids. In addition to these, there are many extra-curricular activities. Dr. Blanke talked yesterday about leisure, and I left thinking, "Who has time for leisure?" But these kids do need to take time for leisure and exercise. As part of their leisure-time activities, we bus them to museums and art exhibitions in Chicago, restaurants, and to shopping malls--which young adolescents seem to really enjoy--and of course, they're involved in all sorts of other social activities.

Faculty Selection

Faculty selection is a particularly interesting process. I wish Dr. Durden had an opportunity to talk a little bit about that, because it is an integral part of the program really, the people who interact with these kids. When I evaluate someone in an interview--and I interview everybody in the institution--I'm looking for four things. One is extreme knowledge in the field. Another is pedagogical skill; just because someone has a Ph.D., doesn't mean she knows how to teach adolescents. The third is a nurturing and caring personality, and the fourth is the ability to be a team player. Our faculty really has worked with me, and they play a significant role in selecting their own team. This year we're adding an audition component which we didn't have; we'll actually observe someone teach. We think that's really important.

University Collaboration

University collaboration is another component of which Dr. Durden spoke, in terms of the talent search program. We developed what we call the University Affiliates of IMSA. I've worked with college presidents from all the universities in our state. We meet on our campus several times a year, and are beginning to develop collaborative programs. Young scholars is another program Dr. Durden spoke of as part of the talent search program. We are beginning to develop such a component. We have a system in Illinois which establishes regional education centers. There are 18 regional centers which were established by the State Board of Education, and we have used those regional centers for the identification of talent and have invited top-scoring math students from each of those centers as 6th graders to the Academy. Last year we had 18, this year we'll have 64. When you bring 6th graders to a school like ours to live with our kids, and have specialized classes they become hooked; so it acts as a potential recruiting mechanism for the Academy as well.

Minority Recruitment

Minority recruitment is a critical area and Dr. Durden spent quite a lot of time on that, it is also an area of concern to IMSA because we're in a large metropolitan area. I underscore the things Dr. Durden said in terms of the talent search. There are talented minority kids out there who already meet the criteria and that's the first kind of minority student with whom we are working right now. We have not yet developed a skills reinforcement program, but we'll be starting that in the summer, and next year. We have established an advisory council to work with us in that regard.

Parent Outreach

Parent outreach is another significant component of IMSA. We have helped our parents by developing a handbook on how to cope with life when their child is away. It had to deal with some of the problems that they face since the family dramatically changes when a significant person has been removed.

Home Schools

We are also working with the students' regular schools and because we feel the need to celebrate and to recognize achievement across our state, we've established our first statewide teacher recognition program. Each of our students recommended the teacher who had the most significant impact on his/her life prior to coming to the Academy. Two hundred fifty teachers were recommended by our students. They will be coming to the Academy to receive recognition. We've also acknowledged the school districts from which our kids come by sending certificates to the school board and to the Superintendent, and I've been invited to actually present the certificate to the school board. When you work in a residential setting you are often perceived as removing talent from the local area, it is necessary to develop programs that will be proactive in acknowledging the expertise within other districts.

That was very fast overview, probably too fast to give you some sense of how the components that Dr. Durden talked about in the talent search program can be used to develop other programs for the academically talented. If you look at the variables of the talent search program, you have a tremendous framework for developing and assessing programs for talented youth. I think the talent search model is an enormously useful one for comprehensive programming. Once we capitalize on the flexibility inherent in the program and the flexibility possible in our educational system, we can do marvelous things if we're willing to take the risk, and if we're willing to use our imagination and skills to develop the potential of students.

Discussant Reaction: The Development of Educational Support Systems for the Academically Talented: The Talent Search Approach

John J. Conger

I don't have a program of my own to present here. Instead, I am an interested observer, as you can tell by my excited involvement with the TIP program at Duke for six years. I would like to say a couple of things, looking at the obverse side of the coin of giftedness, where the glass is half empty rather than half-full. The moon has a dark as well as a bright side, and we have heard about a lot of the brightest and most exciting side here today.

As Dr. Marshall noted, Dr. Durden presented a comprehensive and exciting view of the ways in which the talent search concept has evolved at Johns Hopkins and at Duke. I think that most obviously he made it clear that we can find students who are talented who may not have been identified previously, which is not the same thing as saying we can't identify talented adolescents. We can identify adolescents who are talented, but there still are questions about how many adolescents that are talented are not identified. But having been identified, the student has the opportunity to participate in the talent search program which can foster the intellectual aspirations of young people, enabling them to advance educationally in accordance with their individual talents.

I won't review again the impressive array of programs that were discussed in more detail in Dr. Durden's paper. As an observer, I have to cite personal experience in watching the TIP summer program, and I'm sure it would be the same thing for the CTY program. I've taught everything from children to midshipmen to medical students, and I don't see how you could maintain this intensity for five or six hours a day, but they do. There's a constant interaction and, naturally, the excitement grows. As has also been pointed out, one of the great advantages which these programs provide, other than concentrated intellectual experience and the opportunity to talk about with other people about things that you're both excited about, is the chance to socialize with and get to know as friends other talented students and teachers.

I remember the first time I visited the TIP summer program. I had the chance to go into a course in which I was actually dumfounded--humanities, I think it was. The class had just finished studying different kinds of architecture and now were shifting to music. "Now, what kind of architecture does this kind of a symphony remind you of?" There was silence for thirty seconds and every hand in the room shot up. Nobody was afraid to be wrong. Everyone had a wonderful idea.

Afterward, I had lunch with three boys and three girls in the program. Their average age was about fourteen years. I asked if they liked the program. "Oh, it's really great." "Well, what's the single best thing about this program?" They said that was really hard. A boy from a town of five hundred from Texas informed me that if you read science fiction you were viewed as weird. As a matter of fact, if you read, they viewed you as weird. So he spoke up and said, "I guess if you had to just pick out one thing, it's the fact that back home we're one of them, and here we're one of us."

At this point in the conversation, a young girl said, "Do you suppose when we graduate and get through college we could get together and form a little community and all of us can go along together through life." I said I know what you're feeling, but remember two things: 1) It's wonderful to know and have experiences with people like yourselves and not worry about being intellectually precocious and enthusiastic about learning; and 2) You may want to know a lot of other different kinds of people. I can promise you from having been there that the adult world is a little more diverse than the adolescent world. One kid said, "Yeah, I guess maybe you're right. Besides, it isn't going to make any difference because the whole world is going to blow up pretty soon." This other kid, a fourteen year old, said, "I know what you mean, but you don't mean literally because it's physically impossible to actually completely blow up the world so that there is nothing there." Another kid said, "I know what you're arguing but I've been thinking about it lately and actually it is," and he started drawing diagrams all over the table.

I was sitting there totally awed. The opportunity to have that kind of interaction and the lack of self-consciousness is really terrific. I think these programs and the others which were referred to which are less intense, in some ways, are very valuable resources to a post-industrial society. At the same time, I worry about what are we leaving out and I think that, as Dr. Durden pointed out, no one program can meet the needs of all academically able or potentially able youths. Both speakers talked about identifying kids who already have demonstrated that they are academically able. Dr. Marshall emphasized the identifying of achieved talent in a particular domain and, certainly, that's a resource that we've got to and foster as much as we can, especially in contemporary society where American has certainly had not been holding up its end. But, I think that at the same time, there isn't any program that can meet the needs of all academically able or potentially able students. The focus of TIP and CTY has been has been primarily on kids who have already demonstrated exceptional ability. We also need some sort of minority outreach program, including that wonderful skills reinforcement program in Pasadena that is designed to help black and Hispanic minority students qualify for the CTY annual talent search.

I think that outreach is a good topic for research. But taking the group as a whole, the students were selected on the basis of scores between the eighty-sixth and ninetieth percentile on the CAT and that's a pretty significant achievement. If you figure the background they came from, the eightieth percentile is not the general population. We absolutely have to reach a much larger group of young people in our country than we are reaching even in these programs which have already expanded horizons enormously.

The average Hispanic kid in this country is disenfranchised. Our responsibility is to make sure our schools really work. If you read that survey of eleven major school systems in major American cities, we have a crisis on our hands. Obviously, many kids do manage to achieve and demonstrate academic potential. There are many others who have academic potential, but never have a chance to surface. So, I think we have a potentially great crisis on our hands. We have to turn the whole American educational system around and take very seriously the fact that it's an obligation of the whole community. Talent plus recognition is critical at the top but it is also a continuum that has to go all the way down the line. I would be interested in your observations because, obviously, the TIP community has had an impact on the school districts, giving recognition to teachers who were really in the front lines. And that can't help but have a spinoff effect.

At the same time I think there are still too many school systems that are not being reached. I guess what I'm trying to say is we really need to have a terrific sense of urgency, of how we can do a better job of giving not only talent an opportunity to be not wasted but the potential for talent an opportunity to surface at all, because it's important that young people not be intellectually disenfranchised.

I came from a school in Asheville this morning, where, to my consternation and delight, I graduated. Forty-nine years later the Board of Trustees decided to give me their Asheville School Achievement Award. I went over there and talked to their Sunday night assembly of students. I worked harder at that than I did on any presidential speech. I thought it was over when they handed me a plaque. Then, a boy from the senior class came up and said that they had a literary review when I was there in the thirties, and the magazine had died and they were now reviving it. They went through old issues and came across a series of eighteen poems I had published over a period of three years. They had them formally printed and bound in this book, with illustrations and a beautiful cover. They entitled it *Poems Written at the Asheville School, by John Conger, 1939.*

Now, there was something really exciting about that. It wasn't about what kind of grades I got. But it said something about the total commitment. That would be the last thing that I would comment on. And that is that you have got to be careful about how we nurture talents in the specific domains. A student may be even more excited about the talent he or she has in math or science when surrounded by other kids who are equally talented. But, as you said, we want to make sure they don't get locked into a particular curriculum. You also have to be concerned that we make a positive effort to keep these talented students broad in their liberal education and the arts.

Anyway, this is my last anecdote. I went to Amherst College. I decided to be a poet while I was at Asheville because I was taught by two wonderful poets, one of whom, Eliot Cohn, went on to become head of the Creative Writing Program at Johns Hopkins and educated a whole generation of people who didn't want to become psychologists. I liked Amherst College. I found out the first year that I had to take College Algebra. So, I went to see the Dean and I said I would like to get out of this requirement. It wasn't that I felt that it would just be irrelevant, which it clearly was. I thought it was positively self-destructive for a poet to have to take College Algebra. The Dean remarked, "Well, Mr. Conger, I have noticed over the years that a lot of poets fall into two categories. There are poets who know something about mathematics, and poets who don't know anything about mathematics. I have a strong preference for the first group. So, you will take College Algebra."

I was very impressed with Dr. Marshall's and Dr. Durden's presentations. I wish you great luck in your endeavors. I guess what I'm saying is that what you're doing, you're doing very well. But, make sure you look at the whole picture, the dark side of the moon, too.